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Polarised Light and its Applications to Engineering

Abstract of a Lecture delivered at Southampton to the Southern Branch of The Institution of Mechanical Engineers, by PROF. E. G. COKER, D.Sc., F.R.S., Member of Council.

DESPITE the changes to which mechanical engineering is continually subject, there are some aspects of it which always remain with us, and must ever engage our attention, even although the progress of research and invention make machinery familiar to one generation obsolete in the next.

Among these are the fundamental truths of science. We cannot escape from or evade the laws relating to the motion of solids or fluids, nor the consequences of the laws of thermodynamics, which latter set strict limits on the practical achievements of mechanical engineers, although in some future era, when atoms have been disintegrated completely, there may be surprising consequences with which the engineer will need to deal.

Whatever change the future holds for us, it is fairly certain that engineers will always have the task of designing and building machines for innumerable useful purposes, and this work carries with it the necessity of predetermining the loads in all the parts and of keeping the stresses within safe limits. As every engineer knows, this task is extraordinarily difficult, and can only be accomplished by a combination of scientific knowledge with the skill and practical experience gained in the laboratory and the workshop.

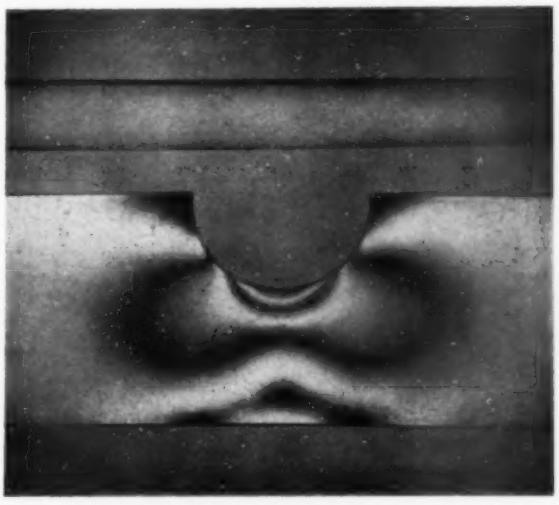


Fig. 1.—A notched tension member in circularly polarised light, with a reference tension member immediately above it.

It is this latter aspect of scientific experiments in the laboratory, and merely one small part of it, to which photo-elasticity is devoted, a branch of applied science in which loaded transparent plate models of parts of machines are used, because when they are viewed in polarised light they show internal stresses just as they occur in the actual members.

The reason why these stress pictures can be seen is that interference effects can be produced with a beam of this kind of light, which vibrates only in one plane, transverse to the direction of the beam, and is, in general, broken up in passing through a stressed plate model into two separate beams, one in each of the directions of the two principal stresses P and Q existing along the line traversed, and since the retardations which each beam suffers, other than that due to passing through a denser medium than air, is proportional to the stress experienced, the relative lag R between the beams causing interference is proportional (*i*) to the difference (P − Q) of the stresses; (ii) to the thickness of the material traversed; and also (iii) to the optical activity C of the material used. We may express this in the simple form—

$$R = C\,(P - Q)\,T,$$

which is the fundamental law of photo-elastic science.

If, for example, we desire to know what is the effect of some form of notch in a beam or a tension member, such as is shown in the plane model Fig. 1, we observe that with polarised white light the model is covered by brilliant bands of colour which tell us that everywhere along each band P − Q is the same, and if we wish to find the intensity along these bands, we can compare their colours with that produced in a simple tension member shown above the model in Fig. 1, which is loaded to some stress intensity S_1, in order to give the same colour effect as that observed at some point of the model itself, whereby the relative lag R is the same in each.

Preferably, this tension member is cut from the same sheet as the model, so that both have the same thickness T, and we then have the simple relation—

$$R = C\,(P - Q)\,T = C\,S_1\,T,$$

or

$$(P - Q) = S_1$$

where S_1 is readily found from the total pull exerted on the tension member. It is in this way that the stresses at the contour of this member are found, due to a total load of 90 lb. at and near this notch, as recorded in Fig. 2. The example is also useful because this simple experimental case is one which no designer of machinery, however accomplished, could solve accurately by calculation. It is in fact one of a great number of cases where theoretical analysis fails, and an experimental solution by photo-elastic means comes to the help of the engineer.

It is of interest to consider another useful feature which polarised light affords in the power it gives us of observing the directions of stress at any point of a plane model stressed in its own plane.

If it so happens that the plane of polarisation of the beam has the same direction as one of the principal stresses, the beam does not divide into two parts in its passage

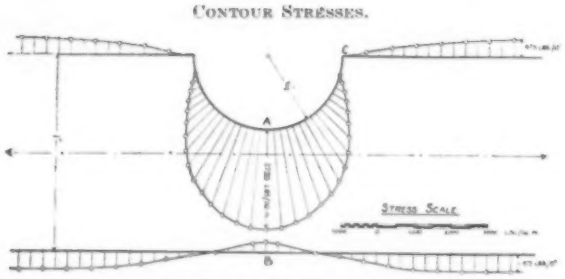


Fig. 2.—Stress distributions along the edges of the notched tension member.

Fig. 3.—The notched tension member viewed in plane-polarised light and showing black bands (isoclinics), from which the directions of stress are found.

through the plate at that place, and it is, in consequence, stopped by an analyser when set in such a direction as to stop all such beams of this inclination. Hence a black point

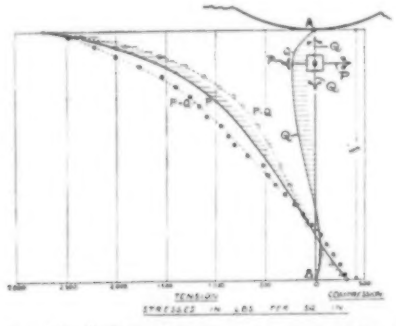
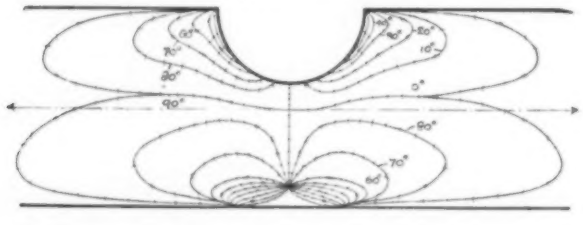


Fig. 5.—Distribution of stress at the cross-section A B of the notched tension member.

or patch appears at this place, and as there are usually a great number of places where the stresses have the same

(*a*) Isoclinics.



(*b*) Lines of Principal Stress.

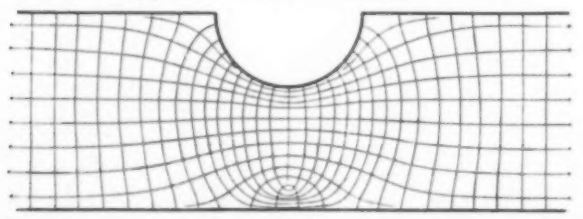


Fig. 4 (a) and (b).—Isoclinics and lines of principal stress of notched tension member.

directions, these run into black bands which mark the directions of stress having the same inclination as the plane of polarisation of the incident beam. Two such bands are shown in Fig. 3 for the notched member already considered, and the centre lines of a number of others are shown in Fig. 4, with the directions found marked on them. This latter diagram gives all the directions of stress in this member, and is complete in itself, but it is usually helpful to imagine lines of stress passing through the member following these directions, and these can be drawn very easily from the information already given, as shown on the lower diagram of Fig. 4.

These isoclinic bands can be swept away if the polarising and analysing prisms are revolved at sufficient speed while keeping their angular alignment constant with respect to each other, for then the bands merge with the background and practically become part of it, or we can make other arrangements to the same end of a less complex mechanical nature, with the equal result that only the colour picture of stress is apparent to the eye.

The practical abolition of the black bands which show the directions of the stresses is usually carried out when stress intensities are under examination.

Only one more measurement is needed inside a plate to render our information respecting the stress at any point experimentally complete, and also quite independent of any but the simplest assumptions. This measurement is

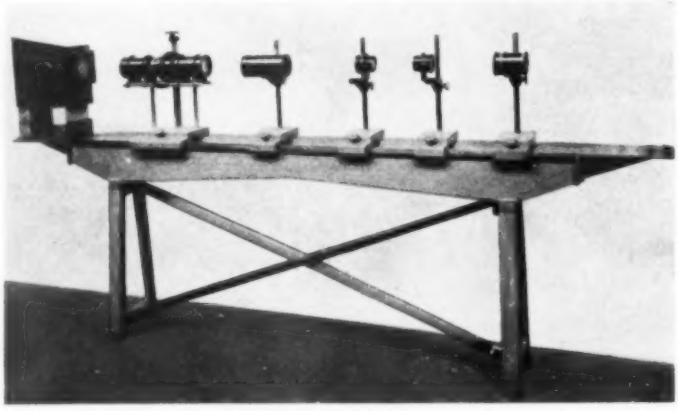


Fig. 9.—Apparatus for photo-elastic experiments designed for use in engineering laboratories and workshops.

required to separate P from Q in the combination P − Q. This can be accomplished in more than one way, but the one selected for description here is to again refer the point in the plate for comparison with a simple tension member. This latter, when loaded, diminishes slightly in thickness, and proportionally to the stress in it. The same kind of change also occurs in the model, but here the effect is due to the sum (P + Q) of the stresses, so that we now have to find the tension or compression S_2, which gives the same result as (P + Q). This can be accomplished readily by an extensometer especially designed for measuring changes of thickness, thereby enabling us to say that some stress S_2 in the calibrating member is such that $S_2 = P + Q$, and since we have already found that another value $S_1 = P - Q$, we have at once—

$$P = \tfrac{1}{2}(S_1 + S_2) \text{ and } Q = \tfrac{1}{2}(S_2 - S_1).$$

It is in this manner that the stress distribution at the cross section A B of the notched tension member has been found, Fig. 5. Thus, it can be seen that we can find experimentally each stress in both magnitude and direction at any point of a plate stressed in its own plane, subject only to the simple optical law $R = C(P - Q)T$, coupled with an assumption, easily satisfied, that the material used

is elastic in the scientific and technical sense, in which this term is understood.

The examination of more difficult examples, of which the photo-elastic method is capable of affording practical solutions, offers much scope, and a considerable choice is available of cases of engineering interest, but only a few will be taken as typical cases.

Modern engineering has for many years past made great use of metal dovetail joints for steam-turbine blading, electric armatures, and many other purposes. It has, in fact, borrowed the idea from the carpenter and joiner, who have used such joints from time immemorial. But in doing so, engineers have departed altogether from traditional forms in order to cope with their own necessities.

Take as an illustration a radial assemblage of dovetail joints symmetrically disposed at the circumference of a disc with a central hole. When all the dovetails exert an equal pull outwards, the state of stress in the disc is revealed, as shown in Fig. 6, like a pattern on a china plate. We note here how perfect is the symmetrical arrangement of the stress distribution produced by equal radial loads, and it is just as easy to show what any other combination of loads will produce, which is statically possible, and also to measure the stress directions and their magnitudes. In this present case it is found that the directions of stress follow the lines of the network of Fig. 7, and this latter

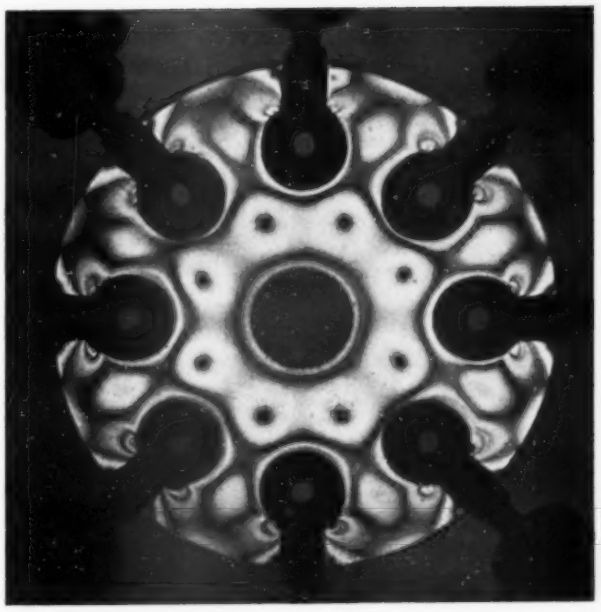


Fig. 6.—A disc in circularly polarised light with dovetail joints loaded by equal radial forces.

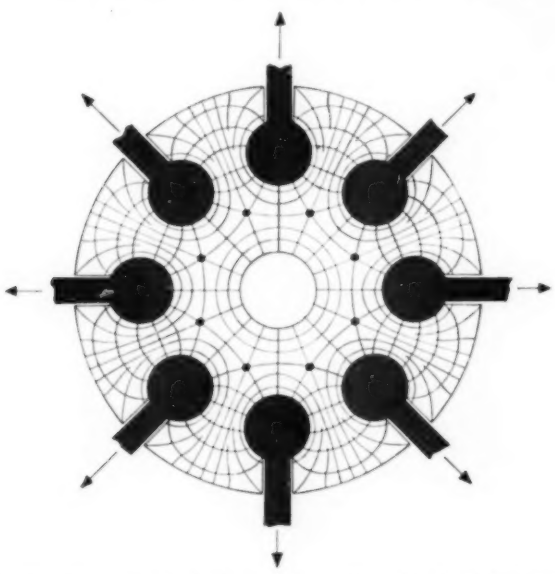


Fig. 7.—Lines of principal stress in a disc with dovetail joints loaded radially by equal forces.

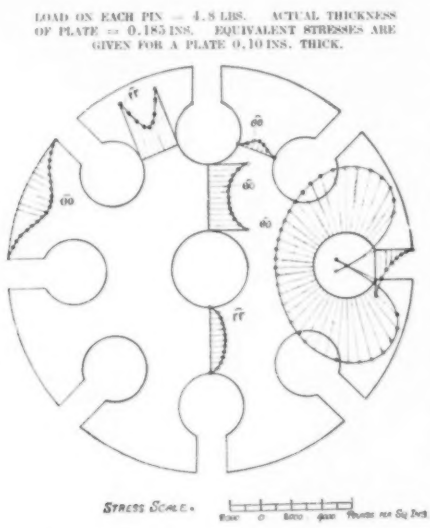

LOAD ON EACH PIN = 4.8 LBS. ACTUAL THICKNESS OF PLATE = 0.185 INS. EQUIVALENT STRESSES ARE GIVEN FOR A PLATE 0.10 INS. THICK.
STRESS SCALE.

Fig. 8.—Stress distribution in a disc with dovetail joints loaded radially and equally.

diagram shows that the octagonal arrangement of black spots in Fig. 6 indicates places where the lines of principal stress intersect at any angle, but at any other place they always cross at right-angles. The reason for this is that at all these neutral points there is equality of the principal stresses in every direction, since P — Q is zero.

It is easily seen from the measurements of Fig. 8 that the stress is intense along the circular edges of the dovetail slots, and its distribution is shown on the right hand of this figure, which also records the radial stresses $\widehat{rr}$ between the holes, which are also large. The same figure shows the circumferential stresses $\widehat{\theta\theta}$ of the outer circular boundary of the disc, and also those along radial sections coinciding with the central lines of the slots.

Having now discussed the elementary principles of photo-elasticity and some simple applications, it may be of interest to refer briefly to the apparatus which has been devised to enable engineers to make their own experiments. One form of polariscope is shown in Fig. 9 mounted on a substantial lathe-bed, so that all the parts can be assembled easily. Light from the lantern on the left is passed through a polarising apparatus, and the parallel beam which emerges then passes through the loaded transparent model of the object which it is desired to examine and afterwards proceeds through lenses, which afford

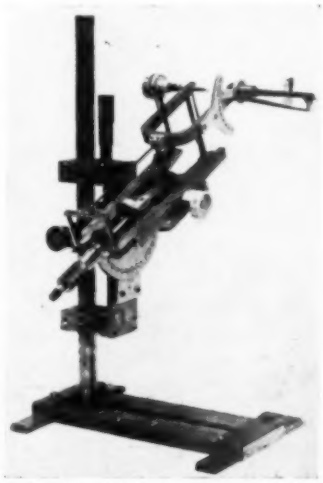


Fig. 11.—A lateral extensometer for measurement work, mounted on a slide rest of special form.

Fig. 10.—The reference tension member mounted in a small portable testing machine.

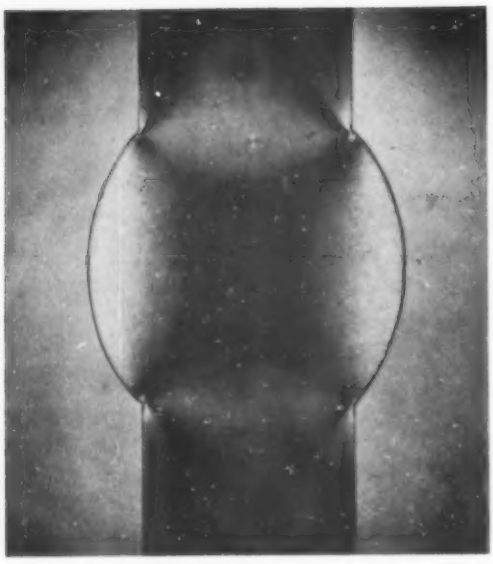


Fig. 13.—Model of a fusion joint in circularly polarised light.

another parallel beam in a space further on, where the reference tension member is set in position. The beam passes finally through an analyser shown on the extreme right, and both the loaded model and reference member are projected on to a screen, not shown here, for detailed examination.

It is clear that the correct reading of the load on the reference tension member determines the accuracy of the optical observations, and hence some means has to be devised which will allow of the load being measured with precision whatever the position the tension member has to take up. The simplest means of accomplishing this is to provide a miniature straight-pull testing machine, such as is shown in Fig. 10, with a spring balance of special design at one end of the frame, and a hand-screw gear at the other. This apparatus is carried on an annular disc in order to permit the passage of the beam of light, and a suitable stand is provided which allows the tension member to be set in any position desired.

The same freedom of movement, but with more precise control is also necessary for the lateral extensometer, which is used for determining the sum (P + Q) of the stresses,

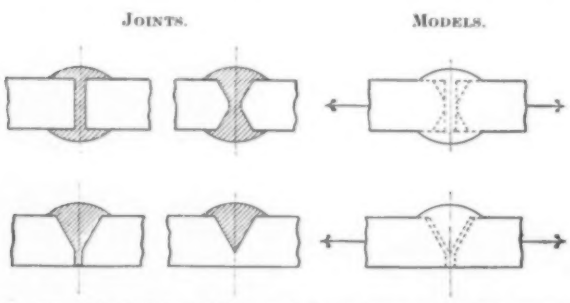


Fig. 12.—Typical butt joints and the transparent models used in photo-elastic experiments.

and the photograph, Fig. 11, shows this instrument mounted on a rather elaborate slide rest, which enables the observer to bring the measuring needle points to any place on the model, and also to determine their position by reference to various micrometers and graduated circles which control the movements of the various elements.

In conclusion, it may be of interest to refer briefly to some important cases of stress distribution which have sprung into prominence somewhat recently. Joints are now being extensively used which are made by the electric arc, oxy-acetylene flame, and other processes, and the stresses in them call for serious attention on the part of the engineer.

Although the merits of such joints, as compared with those made by riveting, have been the subject of much debate and inquiry, the amount of exact knowledge of their behaviour in use is still not very large, and it is desirable, therefore, to scrutinise carefully every aspect of the problem.

One useful line of experimental inquiry is the measurement of the stresses which are imposed under load, since the forms of fusion joints do not allow of accurate stress calculations. Many such experiments can be carried out by photo-elastic means in quite a simple manner, and especially so if the jointing material is taken to be of the same quality as the plates to be connected together.

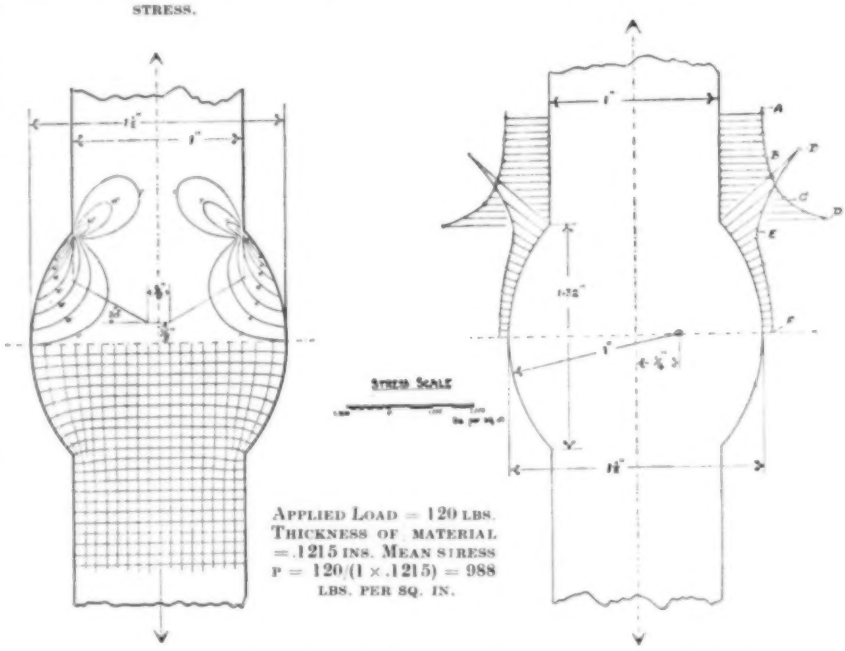

Isoclinics and lines of principal stress.
Contour stresses.
Stress Scale
Applied Load = 120 lbs.
Thickness of material = .1215 ins. Mean stress p = 120/(1 × .1215) = 988 lbs. per sq. in.

Fig. 14.—Isoclinics, lines of principal stress, and contour stresses of a butt joint.

On this assumption, consider, for example, some butt joints of the type shown in section, Fig. 12, so that the models required reduce to the elementary forms of tension members of the same contour shown on the right of this figure. The first model when under load, Fig. 13, indicates, by the concentration of colour bands at the junctions of the curved contours with the straight sides, that the maximum stresses occur at the surfaces of the joint where as it happens they are easy to measure. These observations are plotted in Fig. 14, and show that the maximum intensities are more than two and a half times that in the plate itself.

In the interior of the joint, where the stress distribution is more complex, although less intense, it is again not difficult to find the distribution along any jointing plane. Probably the easiest plan to adopt here is to find the directions and magnitudes of the principal stresses along a number of cross-sections, as shown in Fig. 15. These

observations can then be used to compute stress distributions along any other plane drawn to intersect these sections. The shear stress distribution S along the jointing planes is found in this manner, and is plotted in Fig. 16A, while the normal stresses are shown in Fig. 16B.

The stress distributions in the other joints of Fig. 12 may be treated in precisely the same manner, and when this work is carried out it is found that the maximum stress

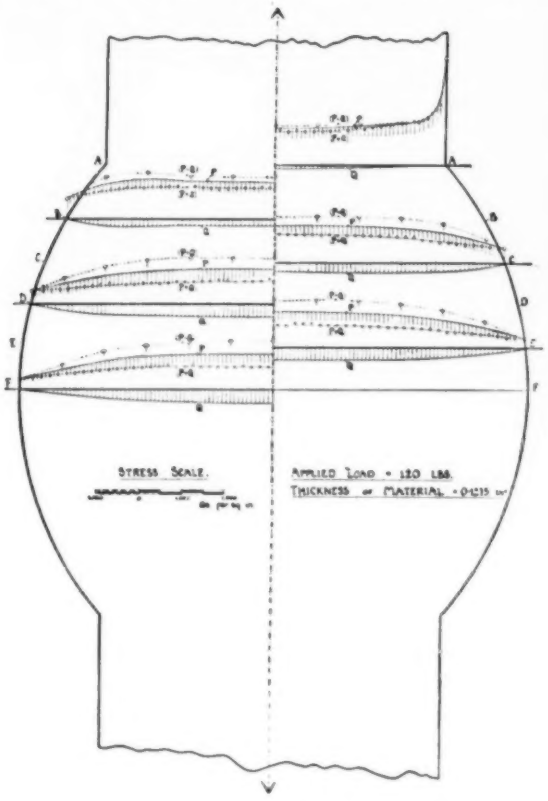


Fig. 15.—Stress distributions in a butt joint along various planes perpendicular to the line of load.

intensities are still found at the junctions of the curved contours of the jointing material with the straight sides. There is no particular difficulty in dealing with many other forms, and the model of a double-butt strap joint, Fig. 17, in tension, is an interesting example of the manner in which stress tends to concentrate at the outermost angles of the fillet welds, and also at the internal angles, as the colour bands indicate and the stress measurements of Fig. 18 show. Here again the model is a section of the joint cut from a single plate and slit along lines where the plates merely bear against each other, by aid of a small twist-drill, but as these slits must have finite widths, however small, it is necessary to insert fillet strips in them so that the bearing contact conditions of an actual joint are preserved.

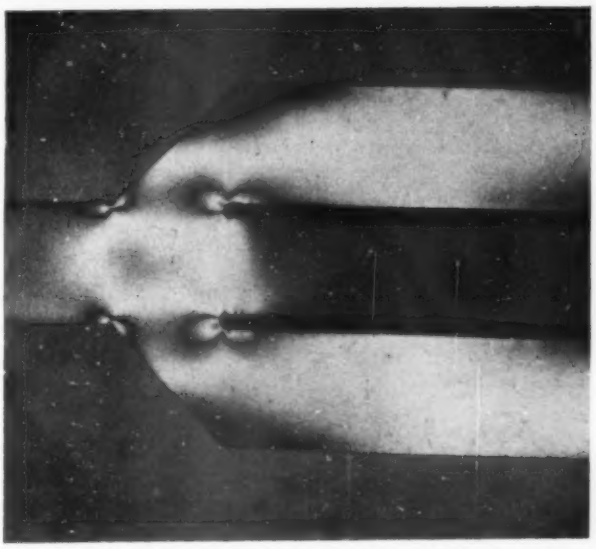


Fig. 17.—Model of double-butt strap joint in circularly polarised light.

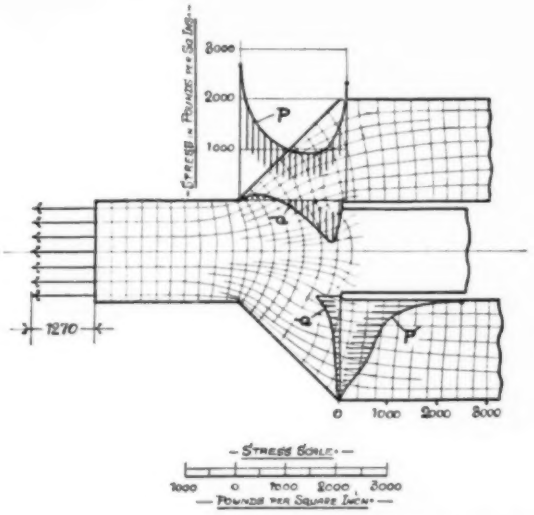
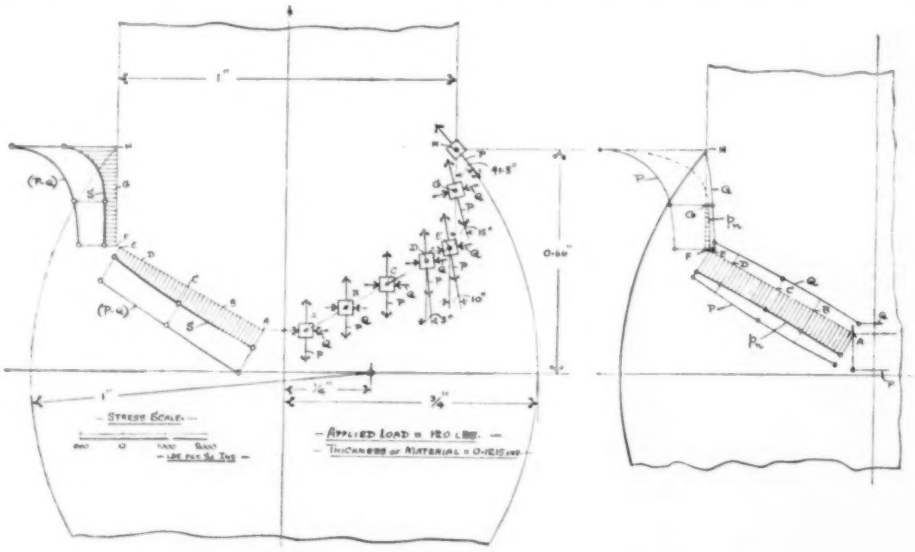


Fig. 18.—Lines of principal stress and distributions of stress along the fusion planes of a double strap joint.



(a) (b)

Fig. 16.—Shear stress (S) and normal stress (Pn) distributions along the jointing planes of a butt joint.

Measurements of the principal stresses at the jointing planes of this example show, Fig. 18, that the stress intensity at the apex of the inner right-angle would become particularly intense if the slits in the model were not well rounded at their ends, and the observations indicate that the stress intensity here is the determining factor in an actual joint. If this internal angle is reduced to, say, 60°, by undercutting the straps, the measurements show a much more favourable stress distribution. If one strap is removed a very high stress intensity is always obtained at the inner angle for quite a low load. In this latter case a filler strip has no apparent influence on the stress distribution.

It is quite possible to cement transparent materials together possessing different physical properties in order to imitate the features of actual joints more closely, and it seems very likely that investigations of this kind will yield much valuable information for the use of engineers.

These typical cases are probably sufficient to show how useful polarised light can be to the engineer when confronted with new problems in the design and construction of mechanical appliances, and how comparatively easy it is to solve them by mechanical measurements by using this kind of light as a research instrument.

May I state, in final conclusion, how much I am indebted to my research assistant, Miss Ruth Levi, Ph.D., and also to my laboratory assistant, Mr. Storrar, for the help they have given in the preparation of the material for this lecture.

The Study of Structural Steel Embrittlement

Is structural steel ductility ranks next to strength itself as an indispensable quality, yet, although very rarely, reports have been received of galvanised structural steel angles breaking with a brittle fracture through a bolt or rivet hole. Due to its great rarity, the phenomenon continued to remain obscure, but, after a failure occurred during erection of a large electrical transmission tower, a systematic research of the problem was begun at Battelle Memorial Institute by the Utilities Research Commission of Chicago, in June, 1930, and by the American Society for Testing Materials in December, 1930. In July of 1931 these studies, which had previously been carried on with a high degree of co-operation between the two bodies, were merged and the work since has proceeded entirely through Sub-Committee X on Embrittlement Investigation of A.S.T.M. Committee A 5 on Corrosion of Iron and Steel under the direction of a Steering Committee.

From the beginning the problem was planned to obtain an engineering solution, and the accomplishment of this aim developed into a considerable engineering research task in itself. Angles in different sizes and in different grades of steel from over 130 heats have been tested very thoroughly in a total of over 3,000 tests.

In all these tests no material of the type spoken of as typically susceptible to embrittlement—that is, described as being ductile in the black but brittle after pickling and galvanising—has come to light, and no direct proof has appeared that it exists. On the other hand, although in the last year and a half not a single failure due to brittleness in a transmission tower or other similar structure has been reported, indicating the great rarity of dangerous embrittlement, the study made has shown that in fabricating and galvanising factors arise which, if not understood and guarded against, may cause angles to show brittle behaviour. It is not easy to say how much ductility is needed in service after a tower has been put up, although a certain amount would certainly seem to be required safely to withstand sudden applications of overloads, such as might arise in violent storms and earthquakes. There can be little question, however, that during the process of erection of a tower, undue brittleness may result in a failure. Such brittleness—that is, failure with little or no deformation at the fracture—is not revealed in the ordinary tension test or even in the notched-bar impact test on unworked material, but shows up, if present, when an angle with a hole punched near the toe of one of the legs is tested in the "angle-bend test." The secret of the different behaviour in the punched-hole angle-bend test from that in the ordinary tests undoubtedly lies in the cold work produced about the punched hole. Impact tests of cold-worked specimens show similar brittleness. The tearing and cracking which occur about the punched hole may contribute toward brittle behaviour, but the test data would indicate this effect to be slight in comparison with the effect of cold working. With drilled or sub-punched and reamed holes, severe brittleness is not encountered except in large Bessemer steel angles.

A corollary to the embrittling effect of punching is the effect of the size of the angle: the thicker the angle the greater the effect of punching, and the greater the likelihood of brittleness. The coarser grain size in the larger angles also promotes brittle behaviour. In the tests made, brittleness was not found in open-hearth angles less than ½ in. thick, very frequently in ½-in. thick angles, but rather frequently in 1-in. thick angles.

The incidence of brittle behaviour increased markedly on lowering the testing temperature, so that these data tended to corroborate reports of angles breaking with a brittle fracture during construction in freezing weather. At 32° F. brittleness is much more marked than at room temperature.

Compared to punching, both pickling and galvanising may be classed as minor embrittlement factors, although not entirely negligible ones, for quite often the larger-sized angles are brought so near the verge of brittleness by the punching operation that the slight additional effect of pickling or galvanising is enough to throw the balance toward brittle behaviour. The embrittlement in pickling appears to be due to hydrogen absorption, and wears off after standing several days. That in galvanising appears to be due mainly to an effect which is now receiving a good deal of attention from research workers in metallurgy—namely, heating to the blue-heat temperature region after cold work (the cold work being due to punching the hole). The penetration of the iron-zinc compound formed in galvanising along the tears and cracks inside of a punched hole also appears to contribute to the embrittlement, but to a minor degree.

Indicated remedies for embrittlement are drilling or sub-punching and reaming larger sized angles, heating to a high enough temperature after punching to eliminate the cold work effect, or the development of a steel less susceptible to embrittlement in punching and galvanising. At present the study is being directed mainly toward standardising the angle-bend test and comparing it with a somewhat similar "hole tensile test," in which a coupon cut from the angle with a hole in it is tested in tension with the view of determining the utility of these tests in specifications. Further work is also in progress on ascertaining more definitely which chemical elements are mainly responsible for embrittlement in structural steel.

The most satisfactory solution of the problem would be the development of practical commercial steel without appreciable susceptibility to embrittlement by cold work. However, the more pressing immediate need is for means of avoiding embrittlement in the present-day commercial structural steel now available in quantity, so the work is orientated directly toward the engineering and testing phases of the problem.

The final report of the Committee directing this work will be presented in June at the thirty-fifth annual meeting of the American Society for Testing Materials.

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

REMOVE DEBTS AND TARIFFS TO RESTORE WORLD TRADE.

APPARENTLY a more optimistic feeling is being engendered in Great Britain in regard to commercial and industrial conditions. It is claimed that a steady improvement in the internal conditions is indicated by a balanced Budget, a reduction in unemployment, by manufacturers beginning to enjoy the fruits of the fiscal change, and by the nation facing the serious position with courage and determination. That courage and determination are essential none will deny, but this optimism is more apparent than real, and only tends to accentuate the thinly veiled spectre of depression existing and which is universal. With every advantage of advanced civilisation, and living in a world of plenty, there is general wa t. Ample facilities are available to supply the needs of all, and political, commercial, and industrial representatives have expressed their willingness to co-operate in any forward policy, and yet little change is effected. There is a distinct lack of confidence and no sense of security, and until these are modified it is obvious that the outlook will remain unpromising.

The aftermath of a war must, of necessity, be a serious time. History shows that after every war, however small, there has been a relatively long period of readjustment. The holocaust of 1914-1918 was of such a colossal kind that it is really remarkable that the world to-day is not in a much worse condition, and it is unlikely that a stable and prosperous condition will be attained for a long time yet. It is as well to realise that the world may not regain its pre-1914 prosperity for several decades, but this period can be shortened by an intelligent appreciation of the difficulties to be surmounted. For four and a half years of war the world was disarranging its financial and industrial machinery; it was endeavouring to destroy the natural influences of progress, and, by the close of the period, industries had attained to a degree of proficiency that they would not otherwise have reached for perhaps half a century. It was natural and logical, therefore, that when peace was restored almost insurmountable problems had to be solved in adjusting the balance of production to consumption and remodelling the machinery of production.

Everyone recognises that these problems must be solved to restore a sense of security in order that projects long overdue can be commenced with a proper feeling of confidence. Yet, despite all efforts to promote normal commercial conditions and resume world progress, stagnation prevails. Evidently the retarding influences are more potent than the influences to which we look for progress, and it would be as well for nations to concentrate on these factors with the object of reducing their effect on world conditions. Few will deny that debts and tariffs are the fundamental cause of the present chaos. It is primarily due to these that the evils of unemployment, unbalanced trade, heavy budgets, lack of credit, currency problems, and general commercial stagnation exist. The debts evil, with which reparations is inseparably bound, is strongly entrenched in the political and economic structure and no method of overcoming its influence has yet been found. To release Germany from her reparation commitments, while leaving the question of Allied debts to the United States unsettled, will only have the effect of adding to the burden of Allied countries. The decision of Congress in refusing to participate in a comprehensive consideration of international indebtedness was regrettable, and yet, in view of the slump now being experienced in that country, it is not surprising; but we are convinced that once they experience a trade revival this question will receive generous support. Meanwhile, however, the Allied countries are bound to give Germany some respite even though their own position is left in doubt.

It is largely due to debts that tariffs have grown during recent years. They have resulted from panic efforts to defeat the consequences of international indebtedness; instead of doing so they have made the position worse, and, at the moment, several countries are threatened with semi-bankruptcy. It seems to be forgotten that the payment of debts is only possible by an expansion of exports; yet trade rivals seek to prevent this expansion by tariffs with the astonishing result that nations demanding payment are doing their utmost to render payment more difficult. It is for this reason that, despite ample production facilities, a substantial proportion of the world's population is living in want—the channels of exchange are clogged with tariffs. It is this desire to create separate economic units behind tariff walls that is the real problem, not only in Europe but in all the countries of the world. World conditions created by panic efforts have forced Great Britain to seek protection for her industries by means of tariffs. It was not possible to remain the only free market for practically all kinds of goods and manufactures.

Let it be stated quite frankly that if tariffs are to have a remedial effect 10% is quite inadequate. A logical case can be made out for the total prohibition of certain iron and steel imports into this country while world conditions remain as at present, although there are few people who would not sooner have a free exchange of goods between the various countries, each of which would buy in the cheapest markets, even from competitors, if those competitors were so favourably situated with regard to the obtaining of raw materials that they could supply semi-finished products, while the standard of living of their workpeople was comparable with that of competitive countries. The iron and steel industries of this country are quite reasonable in demanding under present world conditions that tariffs shall be imposed on foreign imports sufficient to prevent the dumping of materials into this country at a price lower than the cost of production in the countries of manufacture.

The fiscal change of this country paves the way to closer economic relations between the nations of the British Empire, and many have great hopes from the forthcoming conference at Ottawa. There is no disguising the fact, however, that considerable anxiety is being felt amongst some industrialists concerning this conference. This apprehension is not without justification, for the patriotic spirit may be responsible for trade arrangements with the Colonies which would seriously prejudice our position in foreign markets. However valuable an economically sound British Empire would be (and it would provide a remarkable reserve of power), the world's troubles cannot be avoided in this way. The depression is too universal for national plans to have any real effect because all nations are involved in overcoming the evils that exist. The pressing need is

for an international understanding which will break down the barriers that create intangible fears and cause divisions between nations. Let debts and tariffs, which create misunderstanding and disunity, be removed and the trade routes will rapidly reopen and the means of exchange will again be established. These evils act and interact with each other and are fundamentally inseparable. Their influence is world wide, and once removed natural exchange would quickly adjust itself to the world's needs, and there would be less need for the many conferences that merely shirk the real issue and serve no useful purpose.

Natural forces would effect a recovery of world stability more quickly than innumerable national and international commercial and financial conferences. The machinery of exchange and distribution is so delicate that artificial methods of any kind that may be remedial in one way do probably considerably more harm in another. Thus we have the spectacle of countries that are themselves in a deplorable financial condition, lending money to other countries, that are perhaps temporarily worse off, to tide them over a crisis or series of crises, while the causes of these crises are allowed to remain. It is a sad reflection that it has been necessary for France and America to suffer the worst depression in their industrial history before they have been prepared to take the more reasonable view in international financial matters, and it would appear that this trial by ordeal will have to continue for some time yet before there is a world realisation that only freedom in its broadest sense will result in a quick restoration of the world to solvency.

VALUABLE DATA REVEALED WITH POLARISED LIGHT.

IN the design of apparatus, structures, and machines, it is necessary to predetermine the loads in the various parts in order that stresses may be controlled within safe limits. This is, of course, only one of the tasks with which the designer is confronted, but it is one of considerable difficulty, and can only be accomplished by a combination of scientific knowledge with the skill and experience gained in the laboratory and workshop. It is true that methods employed in testing materials of construction and appliances for testing structures and machines have been subjected to many important changes during recent years, but these do not convey complete information concerning the degree and distribution of stresses in a structural member under load. Many appliances are now designed to imitate very closely the conditions existing in a machine when in operation, and these are gradually superseding the more approximate methods which have been customary in the past. Attention is gradually being directed to methods that facilitate the calculation of internal stresses as they occur in actual members, when subjected to loads encountered in practice, and much scientific work has been carried out with this object.

One direction in which developments of this character are being effected is by photo-elastic methods. Considerable work of this nature has been carried out by Professor E. G. Coker, and on page 189 we publish an abstract of a lecture he delivered at Southampton recently to the Southern Branch of the Institution of Mechanical Engineers, in which he described the value of polarised light as a research instrument. The experiments, which he discussed, were carried out on loaded transparent models of parts of machines which could be viewed in polarised light in such a way that they showed internal stresses just as they occur in the actual members. The application of polarised light in this respect enables the observer to detect directions of stress at any point of a plane model stressed in its own plane, and constitutes what might be termed a new field for its employment in engineering. The black bands that are produced by polarised light, by correctly manipulating the polariscope, facilitate measurements which render information respecting the stress at any point experimentally complete, and the method is described.

It is generally recognised that ordinary methods of testing materials do not supply all the theoretical data necessary to meet the increasing needs of modern engineering practice, and there is ample room for the thorough investigation of practically all the modern developments that assist in the solution of problems encountered. The mathematical and physical data that are being provided as a result of the development of the science of photo-elasticity provides an instance, and although the application of this science to industry is yet in its infancy, it provides a method which seems to solve, experimentally, problems that are not readily solved by theoretical analysis. The problems which occur in structures and machines are frequently in combinations of great complexity, in the solution of which photo-elastic methods offer considerable scope. The results of these scientific experiments show how valuable this branch of applied science can be to the designer and engineer.

In view of the interesting facts revealed by the examination of loaded transparent plate models of parts of machines, it may be assumed that the experimental measurement of stresses will open up a new field of employment for polarised light.

Forthcoming Meetings

THE INSTITUTION OF MECHANICAL ENGINEERS.

April 22. General Meeting. "The Film Lubrication of the Journal Bearing," by R. O. Boswell, B.Sc., M.Sc.Tech., A.M.I.Mech.E., and J. C. Brierley, M.Sc.Tech., A.M.I.Mech.E.

THE IRON AND STEEL INSTITUTE.

May 5–6. Annual Meeting, to be held at the Institution of Civil Engineers, Great George Street, Westminster. Following a business meeting, commencing at 10 a.m. each day, there will be four technical sessions at which the following papers will be presented and discussed:—

May 5 (Morning). "Blast-furance Engineering," by W. R. Brown. "Recent Improvements in the Greenawatt Sintering Apparatus," by J. Tornblad. "The Theory and Practice of Nitrogen Case-hardening," by A. Fry. "Some Experiments on the Nitrogen Hardening of Cast Iron," by J. E. Hurst.

May 5 (Afternoon). "The Austenite—Pearlite Inversion," by Sir H. C. H. Carpenter, F.R.S., and J. M. Robertson. "The Influence of the more Common Elements in Inhibiting Needles in Nitrogen-rich Steels and Arc Welds," by L. W. Schuster. "The Lattice Spacings of Iron-aluminium Alloys," by A. J. Bradley and A. J. Hay.

May 6 (Morning). "Fourth Report on the Heterogeneity of Steel Ingots," by a Joint Committee of the Iron and Steel Institute and the National Federation of Iron and Steel Manufacturers. "The Heterogeneity of a Sand-cast Steel Ingot," by A. Kriz. "Behaviour of Manganese in the Acid Open-hearth Process," by E. Maurer and W. Bischof.

May 6 (Afternoon). "The action of Sea-water on Mild Steel," by G. D. Bengough and A. R. Lee. "The Determination of the Porosity of Tin Coatings on Steel," by D. J. Macnaughton, S. G. Clarke, and J. C. Prytherch. "The Properties of some Silico-manganese Steels," by G. Burns.

May 5 (at 7-30 p.m.). Annual Dinner of the Institute in the Grand Hall, Connaught Rooms, Great Queen Street, W.C.

May 12. Additional Meeting at Birmingham.

THE INSTITUTE OF METALS.

May 11. Annual May Lecture in the Hall of the Institution of Mechanical Engineers. "The Plastic Deformation of Metals," by Professor F. Korber, Dr.phil., Dr.Ing.h.c.

AMERICAN SOCIETY FOR TESTING MATERIALS.

June 20–24. Annual Meeting in Atlantic City.

THE EXTRUSION OF METALS.

THE extrusion of metals is now one of the most important processes in the non-ferrous industries, and accounts for nearly all of the bar, tubes and sections produced, as well as a large tonnage of lead pipe and lead cable sheathing. It has been developed mainly during the last 50 years, from the ancient method of producing lead pipe by a primitive form of screw press. The subject was discussed in a lecture delivered before the Co-ordinated Societies recently, by Mr. R. Genders, M.B.E., M.Met.

Extrusion of the soft metals, he said, has developed into rapid processes for producing small articles, such as nozzles, tubes and collapsible tubes, for which small mechanical presses are employed. The extrusion of lead cable sheathing is carried out with specially-designed presses, in which successive charges are welded in the container to give a continuous cable sheath of any required length. Before 1895 the sheathing was made by hand, and the wire pulled through by hand, numerous joints being necessary.

The copper alloys are not sufficiently plastic to be extruded cold, and the high temperature and high pressures required introduce practical difficulties which have gradually been overcome by improvements in materials and engineering design. The relation between temperature and plasticity of the brasses has been studied by various workers.

Application of the extrusion process to brass was first made by Alexander Dick in 1894. The principles of the method used are still retained, and will probably not be superseded for certain types of work. The process was described, and its advantages discussed. In the extrusion of tubes rapidity is desirable to avoid undue wear of the mandril.

The effect of extrusion on the mechanical properties may vary according to factors such as the temperature of the billet, but the material can be made to close specifications. Extruded rod varies in mechanical properties along its length, the grain size gradually decreasing from one end to the other. By annealing, the grain size of the rear end can be increased.

Extruded rods are usually cold-drawn, and in that condition the rod is in a condition of internal stress. Annealing reduces these stresses. In the old process a tubular defect occurred in at least 25% of the extruded material. The defect consists of a core in the centre of the bar, which is often separated from the outer ring by slag, etc. It is not due to piping in the ingot. Investigations on the type of flow which takes place showed that it was due to the outer skin being deflected into the bar. This is in accordance with the laws of viscous flow.

Knowledge of the mode of origin of the defect has led to various practical applications which have proved successful in improving the quality of the product, and in reducing the amount of discard. The billet is now made as close a fit in the container as is practicable, and billets are cast with more care, so that the skin is smoother and less liable to contain foreign matter. The mode of flow is, however, unchanged, and continuous care is necessary to prevent the occurrence of defects. If slip could be induced between the billet and container, there would be no defect, but this is not possible under the conditions met with in the extrusion of brass, and to avoid the difficulty the flow must be altered.

The only method capable of overcoming the defect with certainty is known as the "inverted method" of extrusion. In this method the pressure is applied at the die. In the inverted method, the flow produced is very different from that in the older process, and is confined to a dome-shaped region adjacent to the die. The pressure required is 30 to 40% below that for the direct process, other conditions remaining the same.

So much progress has been made in extrusion processes that practically all the alloys used in the non-ferrous industry can now be produced as rods or tubes. Recently there has been a development in the extrusion of mild steel. One of the advantages of the extrusion process applied to steel is that the surface shaped by the die is not that of the billet, so that a uniform structure free from decarbonisation is obtained. There appear to be considerable possibilities in the extrusion of steel.

Bright Annealing with Hydrocarbon Gases.

Considerable attention has been given to the corrosion of metals under atmospheric conditions, but, by comparison, little thought has been devoted to the corrosion problem occurring during high-temperature operations, such as annealing, forging, etc. Under the conditions of these processes, corrosion or oxidation proceeds much more rapidly than atmospheric corrosion, and the problem is one of considerable economic importance. One aspect of the problem—the prevention of oxidation of metals during the process of annealing—has been investigated by E. G. de Coriolis and R. J. Cowan*, in the laboratories of the Surface Combustion Corporation, on behalf of the Industrial Research Committee of the American Gas Association.

As a result of this investigation, a process for the bright annealing of metals has been developed which is applicable to industry. Apparently, any gas which is not deleterious to the metal, and which will serve as a source of hydrogen may be employed. Pure hydrogen itself may be used, but it has certain severe limitations. Not only is its explosibility a drawback, but its use increases the volatility of zinc when the metal being annealed is brass. Comparative tests indicated that there was a loss of 1.8% of the weight of brass sheets when annealed in a hydrogen atmosphere, as compared to a loss of 0.72% under similar conditions when the annealing atmosphere was methanol and flue gases.

Apparently hydrocarbon gases will prove the cheapest and most available raw material for this bright-annealing process. With their use it is possible to produce the desired amount of hydrogen under suitably controlled conditions. The ready availability and ease of handling of these gases renders them particularly attractive for commercial operation.

The details and the practical operation of this process have been worked out, and it has been adapted to the bright annealing of many different metals and alloys. The metal is passed through a tube furnace in the form of wire or strip. Seals are provided at each end of the furnace, and the hydrocarbon gas is admitted through inlets suitably situated in the tube or muffle. The degree of anneal is determined by the rate at which the metal is moved through the tube. The temperature of the hot zone is maintained slightly above 1250° F. (676.7° C.). Since brass is one of the most difficult of the more usual industrial alloys to bright anneal, the industrial development of this process has been approached with the peculiar requirements of brass in view. It has been found, however, that all other metals and alloys investigated respond in much the same way to the bright-annealing process. The details of operation vary with each metal, but the essentials of the reactions are the same. Steps are being taken to commercialise its applications.

* Coriolis and Cowan. *Ind. & Eng. Chem.* Vol. 24. No. 1, pp. 18–20.

Institute of Metals—Annual May Lecture.

The Twenty-second Annual May Lecture of the Institute of Metals will be delivered by Professor Dr. F. Körber (director Kaiser Wilhelm-Institut für Eisenforschung, Düsseldorf), on Wednesday, May 11th, at 8 p.m., at the Institution of Mechanical Engineers, Storey's Gate, Westminster, London, S.W.1., the subject of the Lecture being "The Plastic Deformation of Metals." Cards of invitation to the Lecture may be obtained from Mr. G. Shaw Scott, M.Sc., 36, Victoria Street, S.W.1.

Development in Non-Ferrous Rolling Mills.

Will readers kindly note that the article under the above heading published in last month's issue of this journal was by Leonard Weiss. A mistake occurred in the name which should be rectified.

The Freezing of Steel Ingots

By J. Cunningham, Wh.Sch., M.I.S.I.

Recent work on the of Solidification of Steel Ingots is discussed with particular reference to recent reports of the Steelworks Committee of the Association of German Ironmasters.

IN the introduction to the Third Report on the Heterogeneity of Steel Ingots (*Journ. I. and S. Inst.*, 1929—I) the Committee emphasised the importance of mathematical analysis in regard to the study of ingot production, and referred to the separation of the ingot from the wall of the mould. This report included an investigation of the effect of latent heat on the solidification of steel ingots, by Mr. N. M. H. Lightfoot, in which it was assumed that the diffusivity, specific heat, and density of the steel were constant for all temperatures, and the same for liquid as for solid steel, as also for the mould. The separation of the ingot from the mould was ignored, although the calculations were extended for periods much beyond those in which this occurs. Three cases were studied, two dealing with masses of steel having only one boundary (semi-infinite), and the other with a slab of constant finite thickness, but otherwise of infinite extent.

This method of analysis has been developed further in two of the recent reports of the Steelworks Committee of the Association of German Ironmasters, both by Dr. Carl Schwarz.[1] In the first the initial stages of cooling were investigated and formulæ deduced for the speed at which the surface of solidification advances, and for the resultant thickness of the shell of solid metal, during the period when metal and mould are in contact. The effects of variations in the initial temperature of the liquid steel, in the temperature of the mould, and in the material of the latter, were examined. A special case of cooling is that of molten metal in ladles, for which formulæ were also deduced, consideration being given to the insulation provided by the ladle lining. In the second report the method was extended to make allowance for the fact that in practice there is not continuous contact between the metal and the mould, and also that the dimensions are strictly limited.

The question of the gap arises in two ways: First, due to the coating of the inside of the mould to secure a smooth ingot surface; and, secondly, through the expansion of the mould and contraction of the ingot. The effect of the coating is threefold, it forming a thin layer of low conductivity, accompanied by the evolution of gas, while the carbon content of the surface of the ingot is increased, with consequent lowering of the freezing point. In view of the short time which is involved it is suggested that these effects can be taken into consideration by using a coefficient of heat transfer, to be determined from practice, the time which elapses between pouring, and the commencement of solidification varying as the square of this coefficient. The numerical value to be given to this coefficient is at present unknown, but the variation of the time of freezing with the different factors is shown in a diagram, from which the following figures are taken for an arbitrarily chosen value of 1,000 kcal. per sq. m. per hour per degree C. These are for a steel freezing at 1,491° C., and show the much greater dependance of the time of freezing on the temperature of the steel than on the temperature of the mould.

Casting temperature	1520° C.		1570° C.		1620° C.	
Initial temperature of the mould ..	0° C.	200° C.	0° C.	200° C.	0° C.	200° C.
Time until surface freezes .... secs.	0·128	0·0415	0·23	0·315	0·665	0·80

The rate at which heat is transmitted across the gap after separation of the ingot from the mould can be at least estimated. Heat is transmitted by radiation, conduction through the gases which fill the gap, and also by convection currents in the latter. Since the gap is only narrow, and there is great resistance to the entrance of air between the ingot and the casting plate at the bottom, it can be assumed that the effect of convection will not be great, and it is ignored in the subsequent calculations. The expression for the radiation coefficient is simplified to

$$k_{\text{radiation}} = 0{\cdot}19\,T_m{}^3 \cdot 10^{-3} \text{ kcal./sq. m./hour/°C.}$$

where T_m is the mean of the absolute surface temperatures of the ingot and the mould, while that for the conductivity of the gases is approximately

$$k_{\text{conduction}} = \frac{1}{s}(0{\cdot}015 + 0{\cdot}55\,t_m)\,10^{-4} \text{ kcal./sq. m./hour/°C.}$$

where s is the width of the gap in metres and t_m the average temperature in the gap in degree C. The total heat transmission is the sum of these two quantities. For a mean temperature of 800° C. and a gap 1 mm. wide, the various coefficients in kcal. per square metre per hour per degree C. are respectively: radiation, 235; conduction, 59; and total, 294.

In considering the solidification of masses of steel with finite dimensions, the evolution of latent heat on freezing is treated as due to sudden occurrence of sources of heat. The underlying idea is that the evolution of a definite quantity of heat within a small compass, of finite size, and in so short a time that it cannot be dissipated—*i.e.*, adiabatic heating—must cause a definite rise of temperature, depending on the quantity of heat evolved and the specific heat of the material. In the case of steel the latent heat is taken as 65 kcal. per kilog., and the specific heat as 0·2 kcal. per kilog. per degree C., from which the momentary rise of temperature is calculated to be 325° C.

The relation between the position of the plane of freezing and the time elapsed from pouring is expressed by a number of laws for different portions of the ingot. For the outer rim the square-root law, $x = q\sqrt{t}$, is employed, where if x be the thickness of the shell in centimetres, and t the time in minutes, q has a value of about 2·5. The thickness of the rim to which this law is applied has to be such that the values obtained by the successive series more or less converge; thus Lightfoot used it to a depth of three-eighths of the thickness for the plate-type ingot. For the next zone the curvature of the time-distance graph of solidification may be expected to be less, and the straight-line law of the form $x - x_n = q_1(t - t_n)$ is found most appropriate. This is similar in effect to, though differing in form from, the expression developed by Lightfoot for the plate ingot, which gave a practically constant speed of advance of the plane of solidification in this second zone.

The conduction of constant quantities of heat per unit of time from the inside of cylindrical bodies, in view of the sectional area increasing with the distance from the centre, gives a logarithmic temperature curve in the solidified portion, falling more rapidly at the solid boundary. With spherical bodies the corresponding temperature distribution is parabolic. From this it follows that for ingots resembling these shapes the freezing velocity increases again towards the centre, becoming infinite at the end of solidification. This means that the middle of the ingot, after being held for a certain time at the freezing temperature, solidifies almost instantaneously. In accordance with this line of reasoning the straight-line approximation to the progressive freezing is replaced by a parabolic one for the last 10 to 20% of the radius of such ingots.

1 Die rechnerische Behandlung der Abkühlungs- und Erstarrungsvor- gänge bei flüssigem Metall, V. *Archiv fur das Eisenhuttenwesen*, September and October, 1931

This can be written in the form $r_n^2 - r^2 = q_2 (t - t_n)$. The test of the application of these various laws, and of the values of the factors q, q_1, and q_2, is the resultant calculated temperature distribution and the temperature at the boundary between the solid and liquid metal.

There is an essential difference between the cooling conditions of ingots cast in the usual manner and those of ingots made by the Harmet process. In the usual case the ingot separates from the mould wall in a short time (2 to 2½ minutes, according to Matuschka), the resultant gap offering a certain resistance to the flow of heat from the ingot. In the Harmet process the ingot similarly separates at first from the mould, but after a further short period extending to the start of the fluid compression, the condition of intimate contact is to a large extent re-established by the pressure. The mould is also cooled during the period of compression. Dr. Schwarz compared the solidification under the two conditions of a steel with a freezing point of 1,491° C., poured at 1,620° C. into a circular cast-iron mould, the inside and outside diameters of which were 546·6 and 820 mm., the ratio of the two being 2 : 3. The physical constants employed were : Steel (both liquid and solid) : Conductivity, 23·5 kcal. per m. per hour per degree C. ; specific heat, 0·182 kcal. per kilog. per degree C.; density, 7,250 kilogs. per cub. m. Cast iron : Conductivity, 25 kcal. per m. per hour per degree C. ; specific heat, 0·14 kcal. per kilog. per degree C. ; density, 7,200 kilogs. per cub. m. The calculations for the ingot cast in the usual manner were based on an average width of gap of 2 mm. and a mean temperature of 800° C., giving heat transmission at the rate of 260 kcal. per hour per sq. m. per degree C. The period of intimate contact between steel and mould was disregarded, partly because of the mathematical difficulties, and partly because it is so short in comparison with the total time that it has little effect on the subsequent results. In the case of the fluid-compressed ingot the mould was assumed to be of steel, the outer surface being maintained at a temperature of 0° C., giving the highest attainable rate of cooling. The short period during which the ingot and mould separate was ignored, continuous contact being assumed.

The calculated temperature changes in the two ingots were shown in diagrams in relation both to position and time. The most important point to be noted in the curves is the location of an arrest or halt in the cooling, in which the whole of the middle of the ingot has cooled from the casting temperature to that of solidification. This is shown in the ordinary ingot as applying to a core 206 mm. dia.—*i.e.*, approximately 38% of the ingot diameter, and to extend from 1·11 hours after pouring to 1·71 hours, at which time freezing was completed. During this period of 0·6 hour, or 36 minutes, the temperature at the centre remains constant. Apart from the considerably faster changes in temperature the diagram for the fluid-compressed ingot shows the surprising result that the inner core in which the temperature fall is arrested is larger than in the other case, the diameter being 236 mm. In this case the arrest occurs from 0·38 to 0·647 hour after pouring, or for 0·467 hour (or 28 minutes). Freezing is completed, as indicated, in the two cases in 103·7 and 50·8 minutes, respectively. The great curvature of the temperature lines, especially after freezing is completed, is a sufficient indication of the necessity for especially careful heat-treatment of ingots after compression. The initial temperature of the face of the mould at the instant of contact was calculated to be 815° C.

The curves of the progress of the freezing from the surface to the centre are similar in shape in the two cases, there being corresponding periods of rapid solidification both at the beginning and end. The principal difference lies in the values of the speed of increase of thickness of the solid shell in the period in which this is approximately constant. This freezing velocity for the ingot cast in the usual way is about 0·2 cm. per min., whilst in the Harmet ingot it is 0·42 cm. per min.

In the discussion K. Eichel communicated the results of tests on 4-ton ingots of rail and soft steels (approximately 590 mm. square) cast into moulds with thick (165 mm.) and thin (120 mm.) walled moulds. The temperature of the mould walls was measured at different depths, from which the rate at which heat was abstracted from the ingots was calculated, these rates being practically the same for both thicknesses of moulds. W. Heiligenstaedt calculated the rate of freezing of one of these ingots on the basis of the heat abstraction, omitting, however, any consideration of the cooling of the liquid steel to the freezing temperature, except at the actual solidifing surface. He gave the velocity of freezing (increase of thickness of shell) as dropping from approximately 1·2 cm per min. at half a minute after pouring, to a practically constant value of 0·22 cm. per min. He gave as a check of his method that an ingot, bled 25 minutes after pouring, had a thickness of 110 to 120 mm., the calculated thickness being 105 mm., the discrepancy being stated as probably partly due to transport delay of the actual bleeding. He further claimed that the results obtained indicated that there was a gap between the ingot and mould practically from the start, no discontinuity being shown in the curves. B. Matuschka (Ternitz), who contributed a paper to the recent meeting of the Iron and Steel Institute on this subject, dealing especially with the influence of speed of freezing on crystallisation, in a written communication supported Dr. Schwarz. From the observed thickness of the shells of 400 mm. diameter ingots, bled at different intervals after pouring, he showed that at about the second minute there was a change in the rate of cooling. Up to that point it had agreed with the values calculated on the assumption that mould and ingot were in direct contact, but after that with the presence of a gap.

Reports of the New International Association of Testing Materials.

THE reports presented by specialists at the first International Congress of the New International Association of Testing Materials, held at Zurich, in September, 1931, together with the discussion, will shortly be published in two volumes. These will contain a collection of highly valuable information relating to practical problems concerning the testing of materials, since they will include all the points, comments, and observations which developed from the discussion on the reports.

The reports were grouped under the following headings :—

Group A.—Testing of Cast Iron, Strength of Materials at High Temperatures, Fatigue, Notched-Bar Impact Test and Progress of Metallography.

Group B.—Natural Stone, Influence of Chemical Agents on Cement and Concrete, Portland Cements, Cements with Hydraulical Ingredients, Aluminous Cements, Concrete (strength, elasticity, compactness), and Reinforced Concrete.

Group C.—Asphalt and Bitumen, Testing of Timbers, Ageing of Organic Substances, Viscosity, and Sampling and Methods of Testing Fuel.

Group D.—Determination of Grain Size in Loose Materials, Calibration and Accuracy of Testing Machines, Fundamental and Test Relations between Elasticity and Plasticity, Toughness and Brittleness.

Altogether, ninety-one reports were presented by specialists competent to treat authoritatively the particular subjects with which they dealt, and since special attention has been paid to the printing, illustrations, and tables, and the style in which the volumes are produced, as well as their general appearance are all that can be desired, there is every likelihood that the demand for them will be considerable.

The two volumes, which are not sold separately, will be available through the office of the British Branch of the Association, 28, Victoria Street, London, S.W. 1.

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part XII.—Rolling Operations.*

The preliminary rolling operations on aluminium slabs prior to finishing to gauge in the production of sheet and coil are further described.

Roughing for Flat-Sheet Production.

In the production of bright flat sheet and grey plate, the rolling operation following slabbing is called roughing. After slabbing, the slabs are sheared to the required length, depending on the thickness of the slab and the finished gauge and length, and sent to the roughing mill. The object of roughing is to continue the reduction of thickness already started by slabbing and prepare the stock for the finishing passes. As a rule, the amount left, on roughing, for finishing is at least 0·005 in., and may vary up to about 0·018 in., depending on the finishing gauge and the practice in different plants.

In some works, the general rule is to rough all slabs (for sheet to finish lighter than about 12-gauge) to within two gauge numbers of the finished gauge. For the lighter gauges, then, suitable allowance is provided by the development of the packs (sheet lighter than 20-gauge being rolled in pack). Roughing may, of course, be split by annealing, depending on the finishing temper. Where required, sheets to finish in certain intermediate tempers are roughed to the annealing thickness, annealed, and then re-roughed to within two gauge numbers of the finished gauge.

On two-high non-reversing mills, the roughing operation is similar to slabbing, as already described—*i.e.*, the sheets are passed into the roll opening by the roller and returned over the top roll by the catchers. Although not previously so stated, slabs are usually slabbed singly—*i.e.*, one piece is worked at a time, except in the case of rather small slab lengths, which may be run in pairs. In the case of roughing, sheets to finish wider than 48 in. and longer than 144 in. are usually rolled singly, while smaller sheets are rolled in pairs. When sheets are rolled in pairs, the catchers are passing one sheet back over the top roll while the roller is passing the other sheet into the mill.

The essential differences in the slabbing and roughing operations lie in the speed of production and number of passes. Thus, slabbing is done with two or three sets of the rolls and five to eight passes, the total reduction in thickness being 0·1 in. to 0·2 in. In roughing, on the other hand, the total reduction is considerably less, being, say, 0·03 in. to 0·06 in. Ordinarily, 10 to 30 passes are made in roughing with three to seven sets of the rolls. The number of passes and roll sets in roughing depend upon the roughing gauge and the condition of the mill. Production may be 500 lb. to 1,000 lb. per hour, in the case of the 99 + % metal.

After roughing, the ends of the sheets are sheared so as to prevent undue cracking on finish rolling, although this may be omitted if the stock is in good condition. In some plants roughed sheets to finish heavier than 20-gauge are not trimmed, but those to finish lighter are squared on both ends and side trimmed. Light-gauge material is more likely to crack on finishing than heavy-gauge sheet. Whether roughed sheets are to be trimmed or not is, of course, governed to some extent by the finishing temper. Thus, aluminium sheets which are to finish in some intermediate temper, such as 2 S 4, and have been annealed during the preliminary rolling, may require no trimming. On the other hand, sheets to be delivered as 2 S 0 or 2 S H which have been rolled full hard, may require trimming. Hard alloy sheet is ordinarily to be trimmed after roughing.

Normally, flat sheet to finish 20-gauge and lighter is rolled in pack, and the packs are developed on roughing. The practice in pack rolling at one plant is indicated by the figures in Table III., which shows the number of sheets in the pack as affected by gauge. All gauges and grades to finish ¼ in. to 19-gauge inclusive are rolled singly, as are sheets to finish 20-gauge in intermediate tempers. The number of sheets run per pack, as influenced by the finishing gauge, varies in different plants, depending on the practice as developed, the condition of the mills, and the grinding of the rolls.

In roughing for pack rolling, the sheets are first given a few passes singly: they are then run two in a pack, then three or four, and finally six or eight, depending on the finishing gauge. The pack is built up gradually as the thickness is reduced. As an example of roughing for pack rolling, the operations on material to finish 20-gauge may be briefly considered. The hot-mill slabs may be cold slabbed to ⅛ in. thick. For the preliminary roughing, the roller will take one sheet and make about six to eight passes with two sets of the rolls. This is repeated for three other sheets, so that the stock is finally run two in a pack and in pairs, there being four sheets on the mill. The allowance for finishing in the case of pack rolling (per sheet) will vary necessarily with the number of sheets in the pack. Thus, sheet to finish at 20-gauge, rolled two in a pack, may be roughed to 19-gauge; this provides an allowance of about 0·008 in. for finishing. Sheet to finish at 30-gauge, rolled four in a pack, may be roughed to 28-gauge; this provides an allowance of about 0·01 in. on the pack for finishing.

TABLE III.

Number of Aluminium Sheets per Pack.

Finished Gauge to be, B. and S.	Number in Pack.
20 (2S0 and 2SH)	2
21 to 24	2
25 to 27	3
28 to 30	4
31 to 33	6
34 to 35	8
36 to 37	16

Sheet stock may be roughed on mills having coated rolls (no buffs or cutting lubricant being used), in which case the material acquires a dull grey, semi-matte finish. In roughing with coated rolls, the sheets and rolls are occasionally swabbed with kerosene to prevent the metal from sticking to the rolls. The matte finish is quickly removed in finishing when the metal is passed through planished rolls equipped with buffs, and this finish is a good basis for the finish rolling of grey plate.

Roughing Coil Slabs.

Aluminium slabs for coil production may be roughed on various types of mills—*e.g.*, two-high non-reversing mills, or continuous mills. In roughing coil slabs on two-high non-reversing mills, the operation differs from sheet roughing (and slabbing) in that the reductions per pass are heavier and the metal is rolled with a cutting lubricant. Coil roughing operations may be classified as first roughing, second roughing, and third roughing (or the run-down). Any roughing operation consists in rolling to nominal gauge or specific thickness, and at the end of the operation the material may be transferred to another mill or annealed.

At one plant, where coil slabs are roughed on two-high non-reversing mills, the practice is as follows: After slab shearing, the slabs are sent to a heavy roughing mill equipped with rolls measuring 22 in. in diameter by

* *Continued from March issue, page* 163.

36 in. face length, and with an automatic coiler. Starting with a slab $\frac{3}{8}$ in. thick, the stock is run to 0·10 in., with five passes, or to 0·08 in. thick with six passes. The slabs are rolled flat until a thickness of about 0·15 in. has been reached, when the stock is coiled by the automatic coiler. Table IV. shows the reductions per pass, and the corresponding roll sets in running slabs from $\frac{3}{8}$ in. to 0·08 in. thick. Fig. 4 shows the operation of roughing-in coils on the mill in question. When the slabs are rolled flat in the preliminary stages, a roller and a helper work on one side of the mill and two catchers on the other side of the mill; two men are required on each side to handle the long lengths. When the automatic coiler is in operation, the mill is run with two men—a roller and a catcher. In this plant rolling to 0·08 in. or 0·10 in. thick is referred to as the first or heavy roughing.

TABLE IV.

Reduction in Thickness per Pass and Roll Sets for First Roughing on Coil Slabs.

Pass No.	Slab Thickness, In.		Reduction in Thickness, In.	Roll Opening, In.
	Entering Rolls.	Leaving Rolls.		
1	0·375	0·275	0·100	0·250
2	0·275	0·200	0·075	0·175
3	0·200	0·150	0·050	0·125
4	0·150	0·120	0·030	0·100
5	0·120	0·100	0·020	0·080
6	0·100	0·080	0·020	0·065

Fig. 4. Roughing Coiled Slabs on a Two-High Non-Reversing Mill.

Coils delivered from the first roughing operation are then given a light or second roughing, or annealed and subsequently second roughed, depending on the finishing gauge and temper. The second roughing is done on a two-high non-reversing mill of the same type used for the first roughing, but of lighter construction. In the plant under discussion, coil is not roughed to less than 20-gauge (0·032 in. thick) on the second roughing mill, irrespective of the finishing gauge. For example, coil to finish 22-gauge is given a light roughing to 0·040 in. (18-gauge), four gauge numbers being allowed for the finish. In the case of coil to finish 22-gauge, the slabs are run to 0·15 on the first roughing mill and then transferred to the second roughing mill. The reductions per pass in running from 0·15 to 0·04 are as follows :—

Pass No.	Reduction in Thickness, In.	Pass No.	Reduction in Thickness, In.
1	0·025	4	0·016
2	0·025	5	0·014
3	0·020	6	0·010

Coils to finish 26-gauge or lighter are given a third roughing, or, as the operation is called, a run-down. The rolling is done on a light two-high non-reversing mill of the type often used for the finish rolling of strip stock. As an example, coil to finish 30-gauge is delivered from the second roughing mill to the run-down mill at 0·032 in. thick, and is rolled to 0·016 in. (26-gauge) with three passes. The reductions per pass are as follows :—

Pass No.	Reduction in Thickness, In.
1	0·007
2	0·005
3	0·004

In some cases, where the finished width of the coil does not exceed 14 in., the third roughing operation is done by "ganging-up" two or more pony mills, the operation then being similar to that on a continuous mill. This eliminates the labour of one or more men.

As has been indicated in the foregoing, the reduction per pass in coil roughing is more or less progressively lessened as the stock becomes lighter, drafts ranging from as much as 0·1 in. on the first pass in heavy roughing to as little as 0·004 in. on the last pass in the run-down. The reductions are necessarily decreased as the thickness becomes less, since there is less body of metal to work upon. Moreover, broadly, the less the reduction per pass the more even the gauge of the coil. As a general rule, in second roughing and running down, the metal may be reduced two gauge numbers per pass. The reductions expressed in decimal fractions of an inch are then progressively reduced as the stock is reduced in thickness.

In starting the heavy roughing, it is of importance to check the slab thickness with the view to finding out whether the gauge is even across the width. If the slab is heavier on one side than on the other, and the first pass is made with the roll set (opening) the same on both sides of the mill, then the stock will emerge with a bow or curve in the edges. When this happens, it is more or less troublesome to straighten the material on subsequent passes. In order to prevent curving or to straighten a bowed slab, the roll set should be made closer on the side to which the slab curves than on the other side—that is, the set should be closer on the light side, so as to extend the metal more than on the heavy side.

TABLE V.

Reductions per Pass : Coil Slabs Rolled on a Continuous Mill.

Stand No.	Slab Thickness, In.		Reduction in Thickness.	
	Entering Rolls.	Leaving Rolls.	In.	%
From $\frac{3}{8}$ in. to 0·08 in.				
1	0·375	0·290	0·085	23
2	0·290	0·205	0·085	30
3	0·205	0·160	0·045	22
4	0·160	0·130	0·030	19
5	0·130	0·105	0·025	19
6	0·105	0·090	0·015	14
7	0·090	0·080	0·010	11
From $\frac{1}{2}$ in. to 0·1 in.				
1	0·500	0·410	0·090	18
2	0·410	0·320	0·090	22
3	0·320	0·240	0·080	25
4	0·240	0·180	0·060	25
5	0·180	0·140	0·040	22
6	0·140	0·115	0·025	18
7	0·115	0·100	0·015	13

In carrying out the roughing operations described above (as well as finish rolling on coil), it is practice to use a suitable metal lubricant on the rolls. The usual lubricants employed include so-called metal roll oils and mixtures of metal oils with kerosene. Lard oil and mixtures of lard oil and kerosene have been used also, chiefly in heavy roughing. The function of a roll oil is to reduce friction

(*Continued on page* 208.)

Aluminium, Its Alloys and Some Applications.

Although relatively a recent development the application of light alloys to industry has made remarkable progress. The ores and the application of aluminium are briefly discussed and the properties of aluminium alloys that are being increasingly used are considered.

THE outstanding characteristics of the metal aluminium are its lightness, high electrical conductivity, resistance to corrosion, and the strength of its alloys. These properties have provided a place for aluminium of ever-increasing importance, particularly during recent years. It is being rapidly developed, and is now employed extensively wherever lightness, durability, and strength are important. Volume for volume, it has about one-third the weight of steel, and some of its alloys, in certain forms, are as strong as mild steel. It is this remarkably low specific gravity, coupled with strength that is opening up new fields for the use of aluminium and its alloys. Its good conductivity, together with other properties, is making it a serious competitor with copper in transmission lines.

Aluminium was unknown to the ancients, although they had a mineral which they named alumen, which, however, was a compound of iron and contained no aluminium. The metal is never found native, and it is only during comparatively recent years that rapid progress has been made in its production. As far back as 1722, F. Hoffman assumed that alum had a separable base, for which the French chemist, Guyton de Morveau, suggested the name alumine. More than a century elapsed, however, before the metal was isolated. Davy, for instance, despite his success with sodium and potassium, failed to isolate aluminium, but he obtained an alloy of aluminium and iron which he named aluminum, from which the present English name of aluminium is derived. The first step towards the production of this metal on a practical scale was made by the Swedish chemist Oerstedt in 1826, when he obtained aluminium chloride. The following year the metal was successfully isolated by Wöhler at Göttingen, but his early products were much contaminated with other substances, and it was not until 1845 that he obtained almost pure globules of aluminium.

Unaware of the work of Wöhler, the French chemist H. St. Clair Deville repeated his experiment in 1854, and subsequently devised two processes for obtaining aluminium, one of which remained for many years the sole means of production on a commercial scale. The materials used by Deville were aluminium chloride, common salt, and fluorspar, a form of aluminium or cryolite, a compound of aluminium and sodium chloride. In 1855, Dr. Percy, in England, obtained aluminium directly from cryolite, and showed the possibility of improving on the troublesome process then in operation.

The purely chemical processes of manufacture have now been rendered obsolete for practical purposes by electro-metallurgical methods. One process devised by Adolphe Minet, was tried on a large scale by two brothers named Barnard, in France, but it was abandoned subsequent to the process devised about the same time by C. M. Hall, of U.S.A., and P. T. L. Heroult, of France.

Ores of Aluminium.

Aluminium is one of the most plentiful and widely distributed of all substances. It comes next to oxygen and silicon in the proportion it forms of the earth's crust, of which the average aluminium content is estimated to be about 8%. It is an essential constituent in nearly all important rocks except peridotites, sandstones, and limestones, and even in these its compounds are common impurities. It is found chiefly in feldspars, clays, slate, schists, micas, etc., and, in more concentrated form, in bauxite and cryolite. The most important of the ores is bauxite, and it has been estimated that 75% of the bauxite obtained is consumed in the production of aluminium, the remainder being used chiefly in the manufacture of aluminium salts, cement, refractories, abrasives, and for the filtering of oil. France, Hungary, and the United States supply about 66% of the total bauxite produced, while Dutch Guiana, Italy, British Guaina and Jugoslavia supply about 33%.

Methods of Extraction.

In the first place, crude bauxite, as it is obtained from the mines, contains silica, iron oxide, titanium oxide in small percentages, water and clay, and it is necessary to refine this material to produce alumina, which is a white substance of substantially pure aluminium oxide. In this way, impurities are removed from the ore which interfere with the successful reduction of the oxide to metal. The compound aluminium oxide, which is used commercially for the production of the metal, may be extracted from the bauxite by several chemical processes, the Bayer process being used most extensively. This process readily eliminates iron and titanium, but dissolves some silica, and it is necessary to use bauxite with a low silicon content. The bauxite is calcined to remove organic matter, and is subsequently ground in a ball mill. The fine material is then thoroughly mixed with a caustic-soda solution in iron tanks, which is treated in autoclaves at a temperature of 150° to 160° C. from 2 to 8 hours under a pressure of 50 lb. to 70 lb. per sq. in., to form aluminate. The charge is then transferred to settling tanks for the removal of the insoluble residue, consisting mainly of ferric oxide, silica, and a sodium-aluminium silicate. The aluminium solution is decanted, diluted, and filtered before being run into decomposing tanks. A small amount of freshly precipitated aluminium hydrate is added, and stirred for about 60 hours, when aluminium hydrate is precipitated from the solution. Subsequently, this precipitate is calcined at 1,100° C. to produce alumina or aluminium oxide, Al_2O_3 which contains 52·94% of aluminium.

The process used for producing commercially pure aluminium is based on the principle that aluminium oxide will dissolve in a bath of fused cryolite or cryolite and fluorspar, and the metal may be electrolysed from this bath by using carbon electrodes. The furnace used for reduction consists usually of a large rectangular steel shell which is lined with a refractory material primarily for insulating purposes, and this is lined with carbon to form the cathode. Carbon bars, suspended by adjustable rods form the anodes. These are adjusted so that they dip into the fused bath of cryolite or cryolite and fluorspar, which contains about 20 to 25% of alumina. The density of the current applied is usually between 650 and 750 amperes per square foot of cathode at 6·5 to 7·5 voltage, and the temperature in the furnace averages about 900° C.

The bath in the furnace is maintained in a molten state by the heat generated from the electric current: the surface, however, is invariably crusted over, and the aluminium oxide is heaped on this crust to act as an insulator and to make use of the heat it absorbs. The oxide is added to the

bath at intervals by breaking the crust. In operation the process causes aluminium to be deposited on the carbon lining, from which it sinks to the bottom of the furnace to be tapped out at intervals of two or three days and cast into ingots. The oxygen is released by the carbon anodes, combining with the oxygen and the consumption of the anodes is very considerable. Theoretically, the weight of carbon consumed from the anodes is 67% of the weight of aluminium produced, but in practice the consumption usually averages between 80 and 90%. For this reason producers of aluminium generally produce their own electrodes.

In commercial practice, approximately 2 tons of high-grade bauxite are required to produce 1 ton of alumina, of which about 2 tons must be reduced to make 1 ton of aluminium, so that 1 ton of aluminium consumes about 4 tons of bauxite.

Properties.

Aluminium is a soft white metal, and in its commercially pure state is relatively weak, which renders it unsuitable for castings and for purposes in which strength is important. It can be readily worked, however, in either a hot or cold state. It is more easily forged or rolled when heated to a temperature varying between 100° and 150° C., while at a temperature of 530° C. it is so friable that it can be pulverised. Aluminium possesses very poor machining qualities, which, in addition to its low mechanical properties, render it unsuitable for many engineering details, but it alloys readily with most other metals, and it is the valuable properties of many of these alloys that have been responsible for the rapid development in the use of aluminium.

At ordinary temperatures aluminium readily oxides, but it is very resistant to ordinary atmospheric corrosion, which is attributed to the protection afforded by a thin film of oxide which forms on its surface. It is a very energetic reducing agent and precipitant of metal oxides and other compounds of metals, in the solid, molten, and dissolved condition. Particularly in the decomposition of oxides rich in oxygen, so much heat is generated that metals which fuse with difficulty, like chromium, are melted, as in the Thermit process. Aluminium dissolves fairly quickly in hydrochloric acid and sodium hydrate; much less readily in sulphuric acid, and only very slowly in nitric acid.

Physical Properties.

Atomic weight	27·1
Specific gravity	2·7
Melting point	658° C.
Coefficient of linear expansion per °C.	$22{\cdot}6 \times 10^6$
Thermal conductivity .. Cals. per cm.² per °C. per sec.,	504
Electrical conductivity (copper 100)	60·3
Specific resistance at 20° C. in michrohms per cm.³	2·85
Coefficient of increase of resistance per °C.	0·00407
Tensile strength (as cast 5 — 7·5 tons per sq. in.)	
(rolled 7·5 — 10 „ „)	
Elastic limit (as cast 2 — 3·25 tons per sq. in.)	
(rolled 5 — 6·5 „ „)	

Alloys.

The addition of small percentages of other elements improves the mechanical properties and machining qualities of aluminium, the most common of these added elements being copper, zinc, silicon, manganese, magnesium, iron, and nickel. Although in most cases the alloying elements increase the specific gravity, the alloys remain relatively light, which with the improved strength imparted to them gives them a distinct advantage over many other metals and alloys for certain classes of work.

Aluminium-copper Alloys.—The most common of the binary aluminium-copper alloys are those known as 3 L11 and 2 L8, containing 6–8 and 12% of copper respectively. The alloys containing about 8% of copper are more ductile, but have less ultimate strength than those of high copper content, which, by comparison, have greater strength at elevated temperatures. These alloys are susceptible to heat-treatment. A greater quantity of copper is dissolved in the aluminium on heating to a temperature of 548° C. than at normal temperatures, and on quenching this supersaturated solution is retained at normal temperatures, but it is unstable and reprecipitation occurs with marked improvement in the strength and hardness of the alloy. This phenomenon, known as age-hardening, is a general occurrence in all systems where a general rise in temperature increases the solid solubility. In the case of aluminium-copper alloys, it has been determined that after heating to a temperature of about 500° C. and quenching in water, the strength of the alloy increases over a period of several days. This ageing period may be reduced by tempering the alloy, after quenching, at 100° C. for a period of about six hours. The effect of such treatment is such that a 6% alloy, which in the chill-cast form will give a tensile strength of about 11 tons per sq. in. with 10% elongation, will give a tensile strength of 20 tons per sq. in. with elongation of 13%.

These alloys are more commonly used for castings, their mechanical properties as cast being as follows:—

Alloy.	Sp. Gr.	Y.P.	M.S.	Elon.	Brinell No.	Izod Impact.
3 L11	2·8—2·84	4—8	10—11	3—6	54—64	2—5
2 L8	2·9—2·96	6—7	11—14	1·5—2·5	74—87	1·0—2·5

Aluminium-zinc Alloys.—The addition of zinc to aluminium increases its strength but reduces ductility. With 13–14% of zinc the alloy has a tensile strength of 10 tons per sq. in. Formerly the aluminium-zinc alloys were used to a considerable extent for castings; they possessed the advantages of being comparatively cheap, were easily melted, and cast into intricate shapes, but they exhibited hot-shortness and cracks developed in castings as a result. The straight aluminium-zinc alloys have now been largely superseded by such alloys as 2L5, containing from 2·5 to 3% copper and 13 to 14% zinc, which is used for gearboxes, crankcases, and a wide range of castings not subjected to corroding influences. The properties specified for a chill test-bar in 2L5 alloy are 11 tons per sq. in. tensile strength and 3% elongation. These are minimum figures, but the average of a large number of tests shows that the following properties may be expected:—

	Sp. Gr.	Y.P.	M.S.	Elon.	Brinell No.	Izod Impact.
Chill cast ..	3·0	6—8	11—16	3—10	65—70	5—7
Sand cast ..	2·99	4·9—6·0	9—12	2—4	62—65	2—4

A series of complex aluminium-zinc alloys with small percentages of other elements, such as manganese, or titanium, which has been developed during recent years, is finding increasing usefulness. These alloys are modified by means of chlorine gas or boron, which have the effect of improving the structure. Such an alloy, with a zinc content of 13 to 14% after treatment, will give a tensile strength of 15 tons per sq. in. on a sand-cast test-piece, which indicates good possibilities for these alloys. They machine easily, and no difficulties are experienced in casting any intricate shape.

Aluminium-silicon Alloys.—These alloys, containing 10% and upwards of silicon, are used for castings, and also as sheet, tube, sections, etc. They have a lower specific gravity than aluminium, and make a special appeal in those instances in which lightness is of primary importance. In addition to possessing moderately high tensile strength and a high degree of ductility, the aluminium-silicon alloys offer considerable resistance to corrosion influences, particularly sea water; they are therefore recommended when light alloys are required to withstand severe corroding conditions. Alloys containing between 8 and 15% silicon show remarkably improved properties as a result of a process known as modification. This consists in treating the metal just before casting with materials which include calcium, sodium and potassium. The process is patented, and although the function of the modifying agent is not yet fully known, the treatment refines the structure and thus improves the physical properties of the alloy.

Typical properties of 10—13% silicon alloy are as follows:—

	Y.P.	M.S.	Elon.	Brinell No.	Izod Impact.
Sand cast ..	5—6	10—12	5—14	45—55	3—7
Chill cast ..	6—7	11—14	8—20	55—65	4—10

These alloys possess good casting qualities, being free from hot-shortness and having comparatively low contraction. They have a wide range of application, particularly for die-castings for motor-cars and aircraft.

Some variations of the straight aluminium-silicon alloys include the D.T.D. 25 alloy, which has a high silicon content, between 10 and 14%, and up to 0·5% of manganese, and up to 0·75% of iron; while there are many proprietary light alloys, such as Alpax, Wilmil, etc., which have a high silicon content. Recent developments have shown that aluminium alloys containing 2 to 3% silicon and about 4% copper have distinct possibilities of considerable value. Such an alloy has been developed in Germany, which, after heat-treatment has a tensile strength of 18 tons per sq. in. with 9% elongation.

Duralumin.—Of the more complex aluminium alloys, duralumin is probably the most well known. The British Standard Specification for this alloy is 3·5–4·5% copper, 0·4–0·7% manganese, and 0·4–0·7% magnesium; up to 0·4% silicon and 0·5% iron may be present. The advantageous physical properties possessed by this material are obtained as a result of heat-treatment and ageing, in which condition it has a tensile strength of over 20 tons. It retains a tensile strength of about 20 tons at temperatures up to 200° C., above this temperature the strength falls rather rapidly. Duralumin is not used for castings, but for forgings, stampings, bars, sheets, tubes, etc., and large quantities in these forms are used in automobile and aeronautical engineering. It is readily hot-worked at a temperature of about 500° C., and after forging or annealing, it may be cold-worked to a considerable extent. The phenomenon of age-hardening which is exhibited by this alloy, follows heating to a temperature of 480° C. for about six hours, and subsequent quenching in water. The hardness increases to a maximum value in about four or five days, but the process may be accelerated by reheating the quenched alloy to a temperature not exceeding 160° C. and maintaining it at this temperature for a few hours. Typical properties are as follows:—

Condition.	Specific Gravity.	Yield Point.	Maximum Stress.	Elongation.	Brinell No.
Heat-treated and aged..	2·79	15	25	15	98

"Y" Alloy.—This alloy was developed by the National Physical Laboratory as a result of research which had for its object the production of a light alloy which would be capable of retaining a high tensile strength at elevated temperatures. The alloy contains 4% copper, 2% nickel, and 1·5% magnesium, while iron and silicon are invariably present as impurities. Like duralumin, its enhanced physical properties are obtained as a result of heat-treatment and subsequent ageing, this alloy being heated to 500–520° C. for a period of not less than six hours and quenched. "Y" alloy retains its strength somewhat better than duralumin at elevated temperatures, and it possesses good corrosion-resisting qualities. It is used for castings as well as for forgings, chill moulds being preferable for the former. Typical properties of this alloy are as follows:—

Condition.	Specific Gravity.	Yield Point.	Maximum Stress.	Elongation.	Brinell No.
Chill cast	2·79	10	11—13	1—2	85
Chill cast and heat-treated .	2·79	14·5–16·5	17—22	3—6	105
Hot-worked and heat-treated .	2·79	14	22	15	105

Condition.	Impact.
Chill cast and heat-treated	3—5

The R.R. Alloys.—These constitute a series of light alloys developed by Messrs. Hall and Bradbury, of the Rolls-Royce Co. They contain small percentages of copper, nickel, magnesium, iron, silicon, and titanium, which vary in proportion according to the purpose for which the alloy is to be used. These alloys have high tensile strength at elevated temperatures, and are used for castings and forged work. They are susceptible to heat-treatment, which improves their properties considerably. The temperature to which the forging alloys are heated is somewhat higher than that for "Y" Alloy—namely, 530° C.,—at which temperature they are retained for two hours and then quenched. The subsequent precipitation treatment is completed by reheating to 170° C. for a period of 20 hours and quenching in cold water. Some typical compositions are as follows:—

Alloy.	Copper.	Nickel.	Magnesium.	Titanium.	Iron.	Silicon.
R.R. 50	1·3	1·3	0·10	0·18	1·0	2·2
R.R. 53	2·25	1·3	1·6	0·10	1·4	1·25
R.R. 56	2·0	1·25	0·80	0·08	1·25	0·6
R.R. 59	2·2	1·35	1·5	0·08	1·35	0·8

The physical properties of these alloys vary, but the following test results are typical:—

Alloy.	Yield Point.	Maximum Stress.	Elongation.	Brinell No.
R.R. 50 as cast	8	14·5	8·5	72
„ Heat-treated	14	16	6	80
R.R. 53 as cast	13	14	3	80
„ Heat-treated	23	24	1	142
R.R. 56 heat-treated	25·5	30	15	140
R.R. 59 „	21	24	8	127

Some Applications.

Although the employment of aluminium is relatively in its infancy, remarkable progress has been made in overcoming its limitations. It is largely in the various transport industries that its application has rapidly developed. The lightness and strength of its alloys has provided a wide field in automobile and aeronautical engineering, but other branches of the transport industry are increasing the demand. Particularly is this true of bus bodies, in which aluminium strength members are now being incorporated in body frames in addition to low-stressed parts, such as panelling and roofing. Large structural shapes of strong aluminium alloys have been produced for use in railway carriage construction, and for such units as cranes and hoists. That the future holds possibilities for suitable aluminium alloys in the construction of motor vessels also is indicated by the construction of a 55-ft. all-aluminium alloy vessel which has been built to Lloyds' requirements.

The introduction of new aluminium alloys of low expansion coefficients for use in making pistons ensures the continuance of the market for aluminium pistons; while steel-cored aluminium conductors are now employed as overhead conductors on every kind of system, from the unobtrusive low-voltage distribution line to the most important long-distance transmission lines. A typical example is the "Grid" system installed in this country, which embodies steel-cored aluminium conductors exclusively. The use of the metal for cables and bus bars is increasing rapidly. Strong aluminium alloy has been introduced as a material for woven fence and barbed wire, because of its durability.

The development in the production of suitable alloys that are resistant to atmospheric corrosion is responsible for steady progress in the use of aluminium as a roofing and sheet-metal material, and for an even greater increase in its use as an ornamental metal on the exterior of offices, shops, and public buildings. Aluminium window frames, sky-lights grilles, balustrades, shop fronts, and other ornamental metal applications, both exterior and interior, satisfy a demand for a white metal that is strong and is easily fabricated.

Heavy aluminium foil or thin sheets of aluminium have been found to offer a protective coating for oil tanks, pipe-lines, storage tanks, and similar structures. This aluminium foil, applied like wallpaper with proper adhesives, is used to protect the underlying surface against sulphur fumes or general atmospheric corrosion, and to furnish a

(*Continued at foot of next page.*)

ALL-WELDED STEEL FRAME BUILDING.

160-FEET CLEAR SPAN CANTILEVER-TYPE ROOF.

ONE of the great advantages of welded structures is the considerable saving in the weight of steelwork necessary, which effects a substantial reduction in erection costs; but there is another advantage which is not less important, particularly when welding is applied to the construction of buildings in densely populated areas, and that is the almost entire absence of noise during construction in comparison with that necessary when rivets are used.

Although more conservatism in construction is encountered in Britain than in the United States or on the Continent, much progress is being made, and what is claimed to be the largest building in this country, in which the steelwork is entirely welded, is the new works extension now being built by Murex Welding Processes, Ltd., at Walthamstow. The structural work which is now in course of erection has been designed and priced on a strict competitive basis. Unlike most of the existing welded buildings which have been designed as for riveted work, with the substitution of welds for rivets, this is an example of a structure designed in every detail to obtain all the advantages to be gained by welding. The lightness and minimum section of every component, the elimination of the usual gusset plates and the complete absence of noise during erection were the first points that impressed the writer on entering the site.

Steel Frame Building having seven 33 ft. bays entirely Arc Welded.

The building covers an area of 37,000 square feet, and has a length of 231 ft., divided into seven 33-ft. bays, and width of 160 ft. The layout of machinery necessitated a clear floor space, resulting in the adoption of 160 ft. span roof. There are 22 ordinary and 110 cantilever-type trusses, spaced at 13 ft. 2 in. centres, suspended from six girders, the girders being supported on twelve braced columns.

The total weight of steelwork is approximately 132 tons, and does not contain a single rivet. The only bolts used are for column foundations, anchor plates to wall on end trusses, and those required for securing the wooden ridge purlins to the top boom of the girders.

In these days of high costs, the most modern processes which promise an increase in efficiency must receive full and careful consideration and be pressed into service. It will generally be agreed that welding has proved itself to be as efficient for many purposes as riveting, and when greater experience has been obtained in its application to steel structures, it will prove a formidable competitor to the older method of construction. It must be clearly understood, however, that the science of welding is not modern in the sense of being recent and theoretical: it has been developed to a much greater extent abroad than in this country, not only in the erection of steel frames, buildings, and in the strengthening of bridges, but also in unique applications such as the construction of steel floors, recently developed by the American Institute of Steel Construction. Welding has, however, to break down, by example as well as by precept, the conservatism in our building practice, and pioneer work now being done will be of great service to the industry in demonstrating the practicability and economy of welded steel structure.

Aluminium and Its Alloys

(*Continued from page* 205).

radiant-heat reflecting surface. On an oil container the lasting brightness of the foil absorbs little solar heat, and reduces evaporation losses by keeping the temperature of the volatile contents at a minimum. The use of aluminium paint has expanded rapidly both in the industrial and in the building field. An important development is the completion of tests of aluminium paint as a priming coat on wood, applied to timber before shipment from the mill. This mill priming is applied by machinery, and gives a protective coating on both front and back surfaces of the timber as well as on the sides and ends. As a step in the economical protection of wood against moisture penetration, this new process and its possibilities are of broad interest in the production of various specialities made of wood.

Calorising, and its Applications

By Walter Smith

The diffusion of finely divided aluminium into the surface of metal parts produces a non-oxidising and non-scaling surface capable of withstanding high-temperature service conditions.

THE process of calorising has for its object the production of a non-oxidising and non-scaling surface to metal parts required to withstand *high-temperature service conditions*. This object is achieved by diffusion of finely divided aluminium into the surface of the metal to be treated, in such manner that a zone of aluminium compound is formed below the original surface of the foundation metal. The zone of compound thus formed is subsequently converted into the δ state, and further diffusion inwards of the aluminium is retarded.

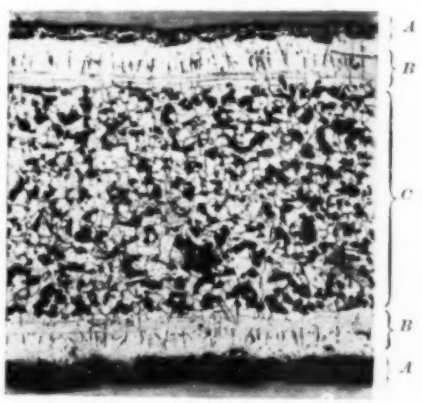


Fig. 1.—Photo-micrograph of calorised mild steel × 100.

The oxidation of the aluminium-rich surface results in formation of a firmly adherent envelope of alumina resistant to further oxidation, and sufficiently close in texture to prevent penetration of oxygen or other destructive media. The underlying metal is therefore protected, and consequently retains, for a greatly enhanced period, the unimpaired strength of its original effective area.

The structure of calorised mild steel is illustrated in photomicrograph, Fig. 1, in which A is the outer envelope of alumina; B is the alloyed zone (δ solid solution); C is the unaffected foundation metal.

The alloyed zone B, in addition to maintaining the protective oxide envelope A, also retards the outward diffusion of the iron of the foundation metal.

During numerous tests, carried out by heating calorised steel for varying periods of time and at varying temperatures, this migration outwards of the ferrite through the alloyed zone has been closely observed; understanding of this phenomena is assisted by study of the reaction during processing.

The diffusion of aluminium into the ferrite, which takes place within the container, results in the formation of an iron-aluminium compound corresponding to the formula $FeA\,l_3$, and this compound may be formed to any degree of penetration, according to the time the treatment is continued. It would therefore appear that under the conditions prevailing during the processing, the diffusion is entirely an inflow of aluminium and the resultant formation of iron-aluminium compound.

On removal of the articles from the retort we therefore have an outer zone of compound $FeA\,l_3$, and an inner zone of unaltered steel. Upon subsequent heating, however, under normal conditions the diffusion appears to undergo a change, and for a time, which is directly resultant upon the temperature employed, diffusion of aluminium inwards, and of iron outwards, takes place until the compound $FeA\,l_3$ is converted into the δ solid solution.

The rate of diffusion now appears to be greatly reduced, and the slow migration of the ferrite outwards displaces an equal quantity of ferrite from the alloy zone until iron appears on the surface.

The rate of diffusion outwards of the ferrite appears to have direct relation to the temperature, and, at temperatures below 950° C., it is so slow that the service obtained from calorised steel is many times that obtainable from untreated steel of similar quality.

From the foregoing it may be assumed that with clean steel of good quality as foundation the resultant condition after considerable service would be the formation of an even layer of iron oxide overlaying the iron-aluminium zone. What usually happens, however, is that the outflow of iron is accelerated in localised areas due to occlusion of impurities in the steel. This, in time, results in the formation on the surface of iron-oxide globules, the growth of which may be automatically arrested by the sealing of the fissure by oxidation of the alloyed surface below, or this localised globular oxidation may slowly extend.

The diagram illustrated in Fig. 2 is typical of results obtained in numerous comparative oxidation tests.

It will now be apparent that calorised mild steel and cast-iron articles may be advantageously employed in practically all service conditions subjected to temperatures

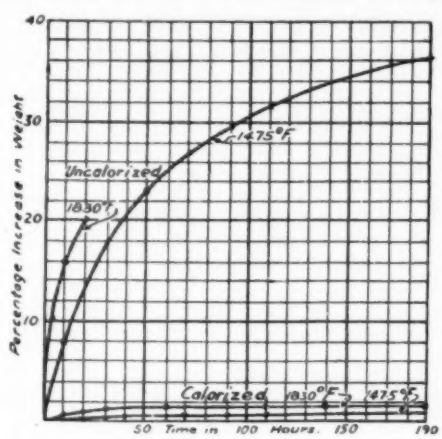


Fig. 2.—Typical results from tests showing comparative oxidation.

from 600° to 950° C. (1,112° to 1,750° F.). Above this temperature mild steel is not suitable as a foundation owing to the accelerated rate of outward diffusion of the iron causing comparatively rapid breakdown. For temperatures above 950° C. it is necessary to employ a steel of special heat-resisting composition, to the use of which reference will be made later.

Scaling of plain mild steel pots when subjected to high temperatures for long periods.

Calorised pressed-steel pots give long service at high temperatures.

Applications.

Calorised steel and iron parts may be used to advantage in the industrial applications enumerated below :—

In the Heat-treatment of Metals.—Calorised casehardening boxes, annealing pans and trays, hardening retorts, conveyer chains, cyanide pots, lead baths, etc., can be economically employed. In these cases not only is the length of service greatly increased, but the detrimental effects resulting from scale reaction with the furnace linings is obviated. This is of especial importance where electric furnaces are employed, as serious trouble may result, due to scale coming into contact with the heater elements.

Furnace Fittings.—Door frames, baffle-plates, dampers, ash shoots, pyrometer sheaths, etc., are frequently replaced owing to oxidation. The cost of such parts may be trivial, but the actual cost of replacement, together with loss of productive time is often a serious matter. Such replacements may often be avoided, and in any case considerably reduced by the use of calorised material.

Cement Kilns.—Calorised mild-steel firing nozzles, lifters, and other internal fittings may be employed in much lighter material than could be satisfactorily used in the untreated state.

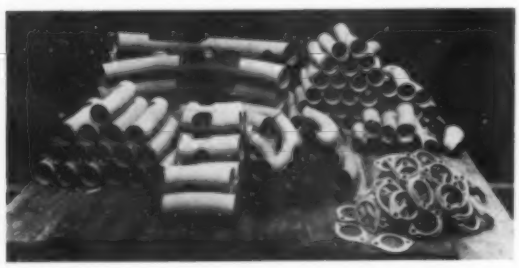
In Ore-roasting Furnaces.—Rabbles and other tools and fittings often rapidly destroyed by oxidation, and sulphurous attack may be beneficially calorised.

Drying Plant, etc.—Heat exchange apparatus constructed of refractory brickwork may be replaced by more compact and more efficient calorised steel tubular constructions of simple design and greater control facility.

Calorising of Heat-resisting Alloys.

It is well known that alloys of the nickel-chromium and nickel-chromium-iron classes are not suitable for service where sulphurous gases are encountered owing to the great affinity of nickel for sulphur, and the rapid breakdown of such alloys is a result of the combining of these elements. This greatly curtails the usefulness of these metals, particularly when one considers the number of cases in which metals having good physical properties at elevated temperatures are called for, but in which these nickel-containing alloys cannot be relied upon owing to the sulphur content of the fuel burned. This sulphur attack is particularly marked at temperatures over 1,000° C., and much more active where conditions are somewhat reducing.

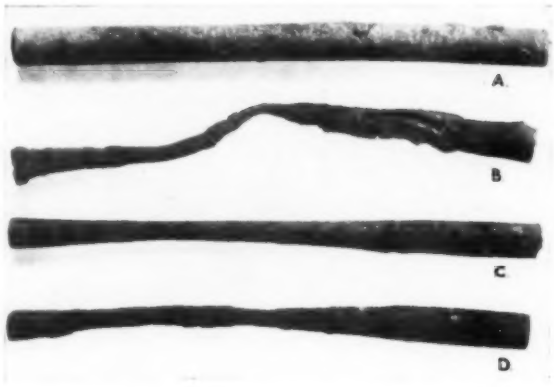
Aeroplane engine exhaust collector parts that have been calorised.



In such cases calorising has been found to give adequate protection against sulphur attack, and calorised nickel-chromium or nickel-chromium-iron alloys may be used with confidence. Furthermore, it is possible to employ calorised heat-resisting metals at higher temperatures than would be practicable with these metals in the uncalorised state, as the rate of oxidation of these alloys is greatly accelerated and becomes comparatively rapid above 1,050° C.

The inert nature of the calorised surface is an additional advantage in that reaction with brickwork or deposited ash, resulting in slagging, and subsequent deterioration of the metal, due to spalling, is less liable than with the oxide surface of most metals.

Fig. 6 illustrates the results of a comparative test on calorised and untreated chromium-nickel-iron alloys, which was conducted, incorporating as far as possible all the conditions referred to above. Specimens are well known chromium-nickel-iron alloys of different composition and manufacture. The specimen A was calorised, while those at B, C, and D were untreated.



Comparative test-results on calorised and untreated chromium-nickel-iron alloys.

The specimens were subjected to the same destructive conditions—*i.e.*, raised from room temperature to approximately 1,150° C. in contact with glowing anthracite for periods of 8 hours' duration, and allowed to cool down as the fuel was consumed. The photograph from which the illustration has been prepared was taken after these specimens had completed 65 periods, or 520 hours of heating. The superiority of the calorised specimen is clearly shown.

Aluminium Sheet Production

(*Continued from page* 202).

and prevent coating formation. Such oils are cut or "reduced" with kerosene, according to requirements, depending on the speed and pressure of the operation. A mixture of 50 : 50 metal oil-kerosene is used considerably in coil roughing.

As has been stated previously, slab stock for relatively narrow sheet and for coil production may be given the preliminary roughing on a continuous mill. The operation consists in running the metal down to nominal gauge—say, 10-gauge,—the material then being coiled and sent to two-high non-reversing coil mills for light roughing and finishing. Table V. shows the reductions in thickness per pass in roughing slabs from $\frac{3}{8}$ in. to 0·08 in. thick, and from $\frac{1}{2}$ in. to 0·1 in., according to the practice at one plant in the operation of a continuous mill.

In the next article of this series the practice in finishing rolling aluminium sheet products will be discussed.

The Advance of Electric Arc Welding

By Edward Dacre Lacy.

The author has had special opportunities of estimating the progress manifest in welding at responsible works in various parts of the country and in this and subsequent articles will be published data determined from the application of welding to a wide range of industries.

At the present time, when the primary industries of the country are so depressed, it is in the interest of all manufacturers and engineering concerns to reduce, so far as possible, their production costs. It is, therefore, the duty of all consulting engineers, designers, and purchasers of raw material to study every available process which is likely to be effective in this respect.

In many fields the electric arc welding process has proved that by utilising this method for construction and repair work a great deal of expenditure can be saved. Many cases have recently come to light of the cheapness of welding as against casting. At the same time it is claimed by the advocates of welding that the process is more economical than that of riveting. In connection with the erecting of steel structures, welding means the elimination of all marking-off and drilling of joists and angles, the members being cut to length and welded up, either in the shop or *in situ*. Also accuracy in fitting is not essential as all small spaces can be quickly filled up with deposited metal which is equal in strength and solidity to the original member. The minimum number of loose tools and component materials are necessary with arc welding, and this offers considerable advantage over other methods of construction.

Recently there has been executed by welding a group of tanks at a large distillery in the North of England, on which the circumferential plating is a departure from standard practice. These tanks, which were made by John Thompson (Dudley), Lrd., are shown in Figs. 1 and 2. The plates are continuous throughout from the bottom to the top, a vee butt weld being employed on the inside and a welded butt strap on the outside. These constructions, the makers are convinced, not only ensure a joint having a strength greater than the plate itself, but also improve the appearance of the structure.

The plates were cut, rolled, and prepared in the works, but the whole of the erection was done on the site without the use of bolts and rivets. The tanks are used for the purpose of conserving large quantities of hot fermenting liquor which gives off a heavy gas at certain temperatures which behaves in a peculiar way. If kept in circulation its action on a plain surface of steel is negligible, but if permitted to remain in the same place for any length of time it has a corrosive effect.

Experience has shown that if the liquor is stored in an ordinary riveted vessel rapid deterioration of the vessel takes place, owing to the tendency of the gas to lodge under projections, such as bonding edges and rivet heads, gussets, etc., where it gives rise to deterioration of the metal. These undesirable conditions indicate the advantages of a tank with a flush interior free from projections of any kind and that was the problem presented when the order was awarded for twelve of these tanks, each 30 ft. in diameter and 25 ft. high. The design developed by the firm's technical department complied with these unusual requirements.

As the major part of the welding had to be done on a vertical surface and a good proportion overhead, it would appear that difficulties and disadvantages would be encountered, but by the use of modern electrodes no trouble was experienced, and all the tanks passed their test entirely satisfactorily.

The sequence of welding when operating on work of this kind is a matter of great importance and care must be taken not to permit the contractional stresses subsequent upon welding to accumulate, otherwise the ultimate stress at various parts of the structure may reach the danger limit, to say nothing of the distortion that must ensue. The manufacturers of these tanks point out that while electric welding provides the strongest and most rigid form of construction, it is futile to regard it as a foolproof operation, requiring no knowledge or experience.

Amongst the welding work undertaken by this company at their Dudley works, are the welding of buoys for the British Admiralty, stainless steel vessels and pans, tar stills, piping of every description, gas and pressure mains, jacketed pans, all size autoclaves, casings and cylinders of every description. Tanks of all sizes for petrol and oil storage, railway wagon tanks, mixers and blenders for artificial-silk factories, and all types of chemical plant. One of these welded jobs is illustrated in Fig. 3. It comprises

Fig. 1.—Welded Tanks for conserving large quantities of hot fermenting liquor.

a mild steel decomposer evaporator casing, 13 ft. 0 in. inside diameter by 15 ft. 9½ in. high, the interior being homogeneously lead lined. It has been constructed for a large chemical works.

Another progressive step in the advance of welding is the erection of an all-welded gasholder for the Southern Oil Co., Ltd. As far as is known it is the first all-welded gasholder erected in this country. When new methods are introduced there are many new problems to be solved. Most of these can be foreseen and provision made; others often arise in the process of executing the work, and have to be dealt with immediately with promptness and skill.

The makers of the gasholder, Messrs. Booth and Sons, anticipated and provided for every contingency, and overcame the difficulties incidental to the site and the adverse weather conditions which prevailed. A specially noteworthy feature of the work is that the welding of the gasholder, both in the works and at the site, was carried out entirely by the metallic arc process, and bolts were used for erection purposes only.

The completed holder, which is 30 ft. diameter by 14 ft. 9 in. deep and has a capacity of 10,000 cub. ft., is

shown in Fig. 4. The tank is made up of ¼-in. plates, all joints having a lap of 1¾ in.; and the holder, ⅜-in. plates, with 1⅞-in. lap joints. The tank bottom of ¼-in. plates has joggled lap-joints flush at each end to present a flat surface to the first tier of shell plates. Considering the thickness of the plates relative to the diameters of the holder and tank, the good shape and absence of distortion are remarkable. This is due to the welding being carried out in such a way that no serious accumulation of contractional stresses was allowed to take place, sufficient to cause distortion or cracking at any point.

The use of lap-welded joints proved to be quite straightforward except in the case of the tank bottom. As the plates had to be laid on the concrete foundation it was not possible to weld on both sides of the joints. To compensate for this the top plates of the joints had a number of 1-in. diameter holes 12-in. pitch, through which welds were made up to the plate underneath. As far as possible plates, curb angles, and superstructure were welded in the shop, the tank bottom plates being temporarily stiffened with R.S.J. sections, tack-welded on, to prevent distortion in transit to the site.

The sequence of erection and welding was as follows:—The sections of the tank bottom were welded together in position on the foundation and the temporary stiffeners removed. The bottom tier plates and curb angle of the holder were next clamped in position and welded, after which the bottom tier plates of the tank were similarly dealt with. In the latter case, however, a continuous curb angle was not used. Instead, angle iron cleats were spaced round inside and the plates welded direct to the bottom on both sides. Following this the second tier plates of the holder and of the tank were erected and completed, and finally, the third tiers of first the holder and then the tank.

The all-welded crown trusses were then fixed to the side of the holder, welded together in the centre, and on these the crown plate sections were laid and welded up. The erection and fixing of the 9 in. by 4 in. R.S.J. standards to carry the superstructure, the superstructure itself, the 4 in. by 2 in. channel guides inside the tank, and the balance weight gear completed the welding. Provision for adjustment of the rollers was made by slotted holes in the guide brackets for the roller pins. For erection purposes and for holding the plates in position for welding, occasional bolts were used, the bolt holes finally being filled up with weld metal, and it was not found necessary to use any elaborate clamping gear.

The sides and bottom of the water tank were welded with No. 8 gauge electrodes, the bell sides and top with No. 10 gauge electrodes. In all cases only one run of welding was deposited. M.W.P. Genex electrodes were used for the majority of the welding both on site and in the shop, but Type XX were used where a heavily coated electrode was necessary.

On the tank bottom and bell top all the seams were tacked up before welding. Then two welders started from the centre, simultaneously, and worked towards the outside to within 2 ft. of the edge of the seam. The remaining tacks on this seam were then broken and the plates thus left free to move, eliminating the possibility of contractional stresses and resultant warping. Each seam was dealt with in this way until welding was completed. All seams were laps and where possible were welded on both sides.

Fig. 2.—Tanks Buttstrap welded on the outside.

Fig. 3.—Electrically welded steel vessel for chemical industry.

Fig. 4.—An all-welded gasholder. The first to be erected in this country

No trouble was experienced with the actual welding, but a great deal of the work on the site had to be carried out in vertical and overhead positions. The creditable way in which the work was accomplished in these circumstances is proved by the fact that the gasholder passed through the official tests without even a single leak. The engineer in charge was so satisfied over this point that he did not require any test on two similar holders which were ordered later to replace old riveted ones. Severe frost and fog held up the work on the site, but in spite of these handicaps the manufacture and erection of the gasholder was completed in a little over six weeks.

Steel Rounds.

We have been informed by the Cargo Fleet Iron Co., Ltd. that they have made arrangements which enable them to supply steel rounds from 2 to 8 in. diameter instead of 2 to 6 in. as previously. In regard to lengths, they can undertake 6 to 8 in. diameter up to 50 ft. As far as other sizes are concerned they can supply:—

2 in.	diameter	and	under	2½ in.	up to	70 ft.	in length.
2½ in.	,,	,,	,,	3 in.	,,	50 ft.	,,
3 in.	,,	,,	,,	4½ in.	,,	45 ft.	,,
4½ in.	,,					40 ft.	,,

In the case of sizes from 4½ in. to 5⅞ in. the limit of length is dependent upon the volume required.

It is of interest to note that this Company also supply rounds from 1 in. diameter up to and including 1⅞ in. diameter, rising by $\frac{1}{16}$ in., and squares from ½ in. up to 1½ in., rising by ⅛ in.

Recent Developments in Tools and Equipment

Suspended Roofs in Furnace Design.

DEVELOPMENT in industry is largely attributed to improved technique in production, which invariably involves development in the design of mechanical appliances and plant to effect the improvement. It is this development that has imposed an increasing need for perfection in the design of furnaces, and every economy possible must be effected in fuel and maintenance costs, while at the same time giving improved heat distribution and increased efficiency. It is with this object that suspended roofs have been introduced in connection with large combustion chambers for water-tube boilers, and the advantages of their use has been fully demonstrated during recent years. Their success in this field has directed attention to their application for metallurgical and other types of industrial furnaces, and it is of interest to note that their adoption for these purposes is also increasing. In the case of large furnaces, suspended roofs often provide the only method of construction which permits the correct functioning of the furnace, but the economy experienced in practice when applied to medium and small furnaces is making their application more general for all sizes of furnaces.

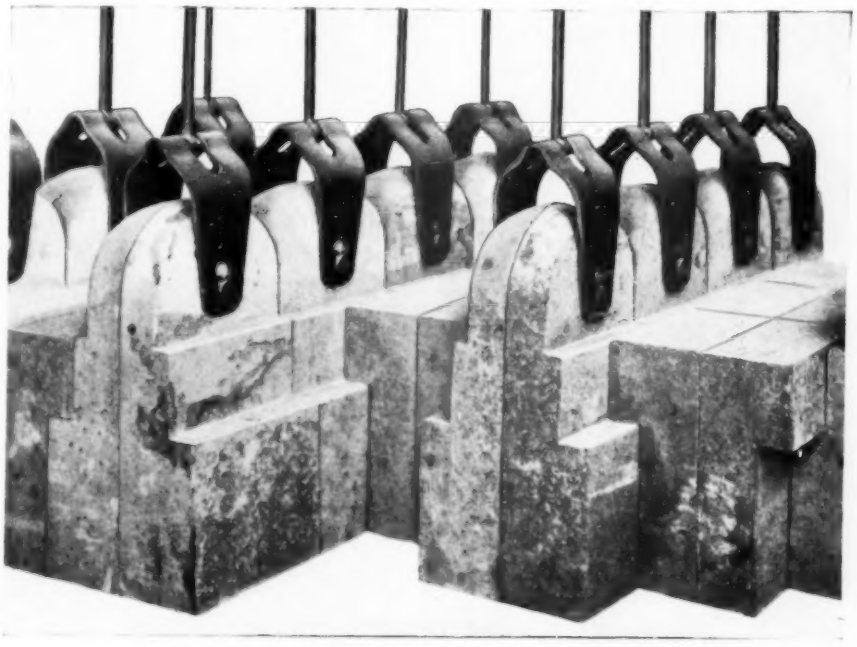
The even distribution of heat, which is so important, particularly when the heat-treatment of special alloys is concerned, is difficult to obtain with a sprung arch, owing to the concentration of radiation towards the centre of the hearth. With spring arches greater space has frequently to be allowed between the underside of the roof and the furnace hearth than is required for the correct flame and gas flow. This excess space is a direct cause of fuel wastage, and may result in excessive scaling of the charge, owing to the flame rising to the top of the arch and permitting a layer of stagnant gases to lie on the hearth. As these gases may contain a considerable proportion of air, scaling is accelerated.

The constructional reasons that are responsible for this disadvantage with the ordinary spring arch, are not involved with a suspended roof, and the free space between the roof and the hearth can usually be fixed to give the most economical results. The contour of the arch need not be flat, but can follow any required curve in order to combine correct gas flow with even radiation.

Apart from fuel economy, evenness of heat distribution and reduction in scaling losses, the suspended roof has many other distinct advantages. When correctly designed, all compression stresses between individual roof blocks are eliminated; this greatly reduces maintenance costs, and since there is no side thrust the life of the arch is considerably increased. A suspended roof can be built to any required width without increasing the depth of arch blocks, and when parts have been burnt thin, they may be renewed without replacing more than the actual blocks which have suffered. It should also be possible to effect repairs of this nature with a hot furnace.

A recent design in suspended roofs has been developed by Messrs. Stein and Atkinson, Ltd. This has resulted from many years' experience in furnace building, during which time many types of roof construction have been tried. Careful attention has been given to details, and the designers believe that the result closely fulfils the requirements of an ideal roof.

As will be observed in the accompanying illustrations, each alternate block in this roof construction is supported by a round steel bar or pin passing through a hole which is formed through the centre of the upper part of the block. As arranged, the blocks are free to move in any direction in a horizontal plane. This complete freedom of movement eliminates the accumulated stresses resulting from rigid suspension or wedging action. The circular pin is the only supporting member that passes through the refractory, and the material at this point never attains any high temperature, even when the lower part of the block is burnt right back, because the upper ends of these blocks are well above the level of the intermediate blocks, and consequently receive adequate air ventilation. The main structural supports also are well clear of the roof.



A recent design in suspended furnace roofs, showing method of assembling blocks.

In this design any individual block can be replaced with ease. Providing the undersides of the blocks have not become fused together, any intermediate block can be lifted out. Any block that is directly supported can be replaced by first withdrawing the intermediate blocks on each side of it, and then slightly raising the block to allow for the removal of the pin.

The design facilitates a modification in the contour of the arch if at any time it is found to alter the height. This can be done without structural alterations, as it only involves screwing up or down the nuts on the upper ends of the vertical supporting rods. If the required adjustment exceeds the limit of movement obtainable by means of the screw, it is a cheap and simple process to substitute longer or shorter T-headed bolts.

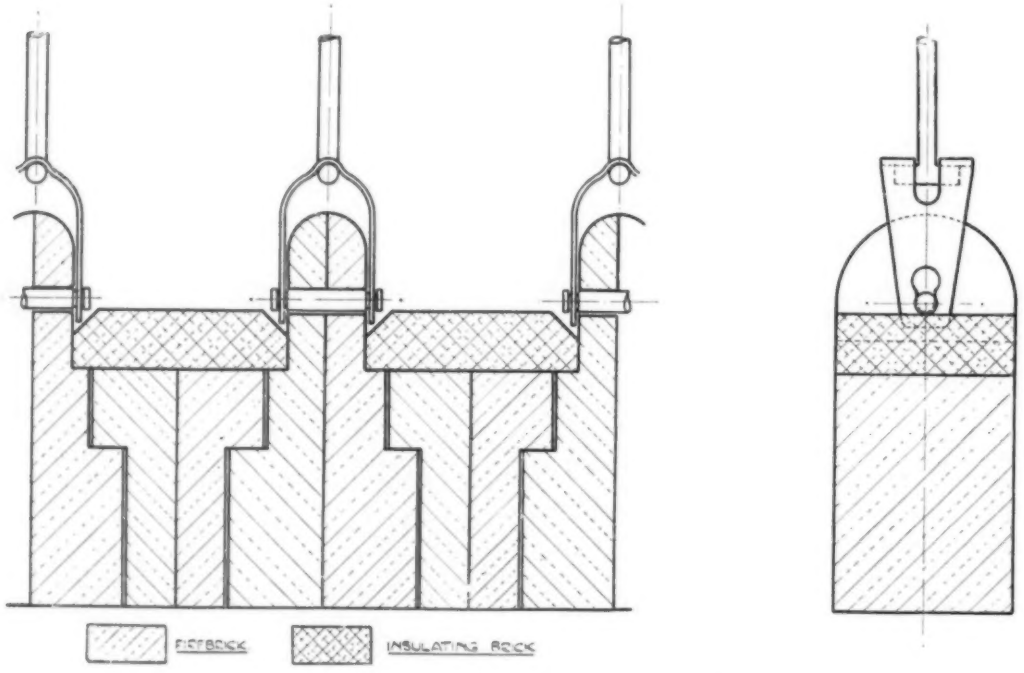
The choice of refractory materials for the furnace roof depends upon the working conditions, such as furnace temperature, and whether or not the temperature is required to be maintained uniform over lengthy periods, or is subject to frequent heating and cooling. When the roof must stand up over lengthy periods to high temperatures, which are maintained more or less uniform, a high-grade silica block is used in its construction: if, however, it is required to withstand rapid heating and cooling and high temperatures are involved, then a highly aluminous block is used which possesses an exceedingly high softening temperature with a low coefficient of expansion. Correct proportioning of the grain structure of the block is of the first importance, in order to combine mechanical strength with high resistance to spalling. For moderate temperatures, good results are obtained from other refractory materials which permit of an important economy in first cost.

For the great majority of furnaces operating at moderate and low temperatures, the addition of insulation to the walls and crown will effect a considerable saving in fuel. This new suspended roof has been designed with this end in view, and is very readily insulated, as shown in the accompanying illustration, by using standard insulating slabs or insulating powder. The drawing clearly shows that there is no risk of overheating any of the metallic supports, as would be the case were the insulation carried outside them.

It should, of course, be borne in mind that on many high-temperature furnaces it is not desirable to provide special insulation over the refractory blocks of the roof, otherwise these blocks would be too rapidly burnt back, and the cost of renewal of the blocks would be greater than the saving effected, due to the reduction in fuel consumption obtained by insulation.

A New Aluminium Solder.

The increasing use of aluminium and its alloys in many fields has necessitated the use of special solders, not only for carrying out repairs, but also to facilitate fabrication of parts. Many difficulties are presented in the soldering of aluminium, and considerable research has been involved to simplify the process, and yet produce an effective joint. The greatest difficulty is undoubtedly due to the rapidity at which oxidation taken place on the surfaces of parts to be soldered, and on the newly-tinned surfaces. This difficulty apparently is overcome by means of a special solder which has been developed recently. It has been given the name of N.U.E. solder, and is marketed by Messrs. B. J. Hall and Co., Ltd., Stourton House, Dacre Street, London, S.W. 1.



Diagrammatic views showing assembly method of insulation.

The experience of preventing or lessening oxidation by covering the newly-bared surface to be soldered with a flux has generally been recognised as an inadequate compromise, and in the solution of the oxidation problem it has been appreciated that chemical methods were necessary. But, while incorporating an ingredient capable of breaking down the oxide film, it was necessary to exclude all such chemicals as might reduce the ultimate strength of the soldered joints. This new solder is claimed to make joints as strong as the virgin metal, and to make possible the true soldering of aluminium.

The process of soldering is extremely simple, and consists of brushing and cleaning the fractured part or parts which are to be joined. A wire brush should be used and, if necessary, the parts should be filed or scraped to

expose clean metal. The parts are then heated in an open flame until they are hot enough to melt the solder when applied to them. The molten solder applied to the parts in this way is rubbed vigorously over the surfaces to be joined by means of a wire brush. This has the effect of "tinning" the surfaces, and a further application of the solder over the whole of the surfaces can be effected without any flux being used. The two surfaces prepared in this way can be joined by heating them together and, if properly done, a sound, reliable joint will result.

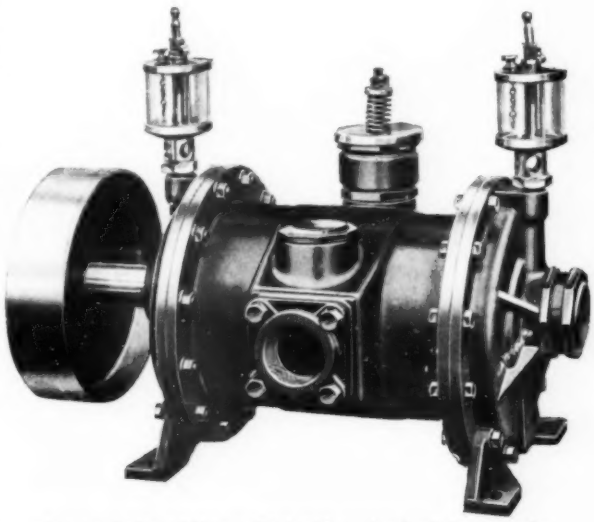
A copper bit may be used, if more convenient, in a manner similar to that adopted in soldering other metals; but the "tinning" operation should precede the application of the solder with the bit. This latter method is useful for filling up holes or in building-up parts that require to project.

This solder possesses several other advantages: its strength, for instance, allows of it being machined, turned, milled, tapped, and moulded in order to reform a broken casting, or for many other purposes. Further, it enables two different metals to be joined together effectively. Thus, aluminium can be soldered to brass, steel, or copper, and as its electrical resistance is extremely low, it offers possibilities for a wide range of applications necessitating this quality. The solder is not attacked by chemicals which do not attack aluminium, nor is it affected by conditions that do not affect aluminium. We understand that samples of this solder are available, and those interested should communicate with the distributors.

A Rotary Blower with New Features.

THE rotary blower, in which sliding blades operate by centrifugal force, is well known. It discharges a given volume of air per revolution, but considerable care must be exercised to maintain the blower in efficient working order, otherwise the blades tend to seize against the wall of the cylinder and the blower ceases to function. This is caused by the blades under centrifugal force breaking the film of oil which should exist between the blades and the cylinder. Even when the blower continues to operate, considerable power is consumed in delivering the quantity of air required.

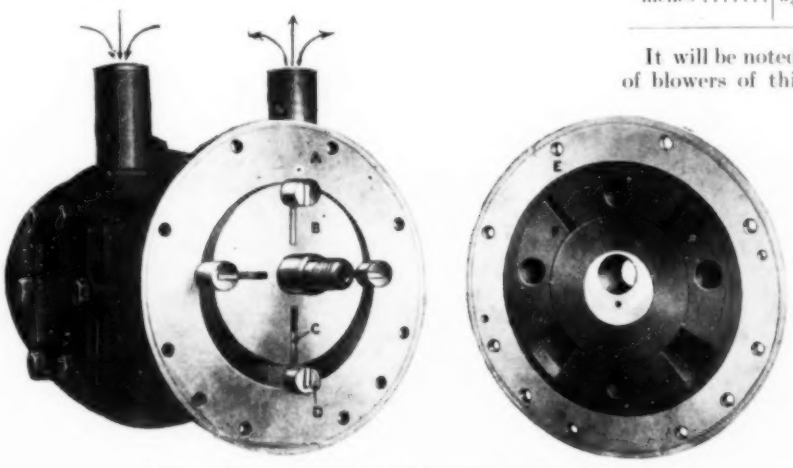
A recent development in this type of blower has been marketed by Daniel Foxwell and Son, Ltd., of Cheadle, near Manchester. Its most important feature is the method of controlling the blades, which prevents them being forced hard against the cylinder wall, reducing the power necessary to drive it, and preventing undue frictional heat, wear, and noise. The method employed is by extending the blades beyond the cylinder and fitting rollers to these extensions, as shown in the accompanying illustration. In each of the cylinder-end covers is a ball-bearing mounted floating ring moving concentrically with the cylinder. In a groove in the ring are a number of segments—one for each blade—having holes in them to receive the ends of the blades with their rollers. The illustration shows the design of one of these blowers with a cover removed. It will be noted that, whatever the speed of rotation, the edges of the blades cannot be forced hard against the cylinder wall by the centrifugal force. The oil film is thus preserved, and no wear on the blade edges or cylinder wall is likely. The arrangement gives perfect contact with the minimum of friction, resulting in a relatively high output with low power consumption.



A general view of blower fitted with spring loaded relief valve.

This type of blower can be made to any capacity, but standard patterns have the following dimensions and capacities:—

Size	4½ in.	5 in.	7 in.	9 in.	10½ in.	12 in.
Dia. of cylinder	4½ in.	5 in.	7 in.	9 in.	10½ in.	12 in.
Length of cylinder	6⅝ in.	7½ in.	10¼ in.	13½ in.	15¾ in.	18 in.
Revs. per min.	1,600	1,574	1,264	1,050	958	900
Displacement, cub. ft.	40	65	140	245	356	500
Floor space in inches	12×8	15×10	19×12	24×16	30×19	32×21
Net weight, approximate lb.	51	81	184	330	519	750
2½ lb. sq. in. output, C.F.M.	30·0	48·0	106·0	220·5	320·4	450·0
H.P.	0·8	1·3	2·8	4·9	7·1	10·0
5 lb. sq. in. output, C.F.M.	26·4	45·0	100·0	208·2	302·6	425·0
H.P.	1·2	2·0	4·2	7·3	10·6	15·0
Size of pulleys in inches	5¾×1⅝	6¾×1⅞	9¾×2½	12×3	14×3½	16×3½

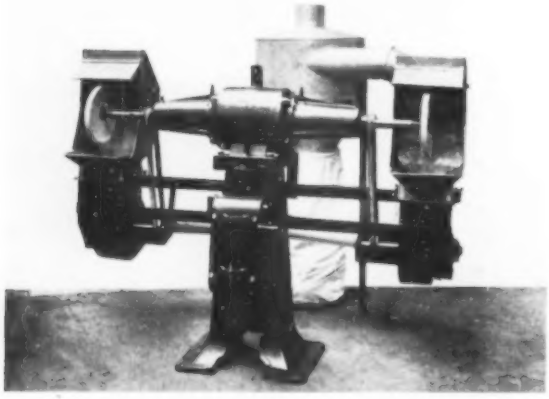


Blower with cover removed, showing rollers at ends of plates.

It will be noted that, in comparison with other designs of blowers of this type, the higher speeds at which the blower can efficiently operate permits the use of smaller machines for a given displacement, thus reducing first cost, in addition to saving space. It can be fitted with a spring-loaded relief valve to allow for the use of a valve or cock to control the quantity of air delivered. It is of interest to note that the rotor is also mounted on ball bearings, and the lubrication system which materially reduces the power consumed for a given output is simple and efficient. We have had the opportunity of examining one of these blowers, and find that the workmanship leaves nothing to be desired.

Polishing Motor with Dust Extracting Unit.

The rapid development in the demand for higher metal finishes, on mass production lines, has necessitated considerable activity in the design and manufacture of machines capable of meeting this demand. The ingenuity displayed in devising machines which have proved so successful in eliminating the tedious, lengthy, and costly operation of polishing that formerly existed, has developed an efficiency that has not only reduced production costs, but has given an improved finish to the work, and enabled greater consideration to be given to the comfort and health of workers. This is supported by developments in dust extracting plant that are continually being effected. The polishing motor shown in the accompanying illustration provides an excellent example. Made by Messrs. W. Canning and Co., Ltd., of Great Hampton Street, Birmingham, it is fitted with a dust extractor recently



Polishing Motor with Dust Extracting unit, by Messrs. W. Canning & Co. Ltd.

improved to satisfy the requirements for individual units. This form of dust extractor can be attached to polishing lathes or, as is shown, to polishing motors. The sheet-iron mop hoods are fitted with adjustable trays and cowls, and trunking connects with a cyclone dust collector at the back of the machine. In addition, independent fans are provided for each hood.

The polishing motor, to which the extractor unit is fitted in the illustration, is a machine familiar to the metal finishing trades. It is designed to run at efficient polishing speed, and is provided with extra bearings where they are most necessary, the snout having a bearing at the end in order to strengthen the spindle, and enable it to withstand the polishing load. The machine is, therefore, equipped with four bearings, two on the inner shields of the motor, and two on the outer ends of the snouts. The motor is totally enclosed, and runs for long periods without attention to the bearings.

Nickel-Steel Plates.

The increasing use of alloy steels in general engineering is an interesting sign of the desire to take advantage of the higher stresses for which these materials are useful, whilst at the same time reducing weight.

Keeping pace with this trend the Appleby (Lincs.) works of The United Steel Companies, Limited, which has previously manufactured only mild and medium carbon steels for boiler, ship, bridge, tank, and similar structural purposes, is now manufacturing nickel-steel plates in all sizes from $\frac{1}{8}$ in. thick upwards.

Nickel-steel plates are now in much use for automobile and heavy vehicle chassis frames, brake-drum pressings, as well as for structural engineering purposes, bridge and railway work.

Behaviour of Manganese in the Production of Steel.

In a communication from the Kaiser-Wilhelm-Institut, published in *Stahl und Eisen*, February 11, 1932, referring to Report No. 221 of the Steel Committee of the German Ironmasters Association, Friedrich Körber describes some researches into the behaviour of manganese in the production of steel. He has determined, as a result of laboratory experiments, that the relative proportions between iron containing manganese, and slags consisting almost wholly of the oxides of iron and manganese, became fixed in the range of temperature between 1,520°—1,950° C. Assuming the possibility of applying the simple mass-effect law the constants of manganese proportions between the fused metal and slags were calculated. Estimations of oxygen showed an almost linear rise of oxygen contents with temperature. It is shown that the solubility of the manganese protoxide in the metal is unimportant in comparison with that of iron protoxide.

Making use of the solidification diagram of the system FeO—MnO, and accepting the additivity of the lowering of the melting point of iron, by means of oxygen and manganese, the regions for the separation of liquid and crystallised deoxidation products from the metal were limited to the concentration plane (Mn)—(O_2). By means of a completed diagram of the deoxidation of manganese, a graph of which is also given, the separation of the order of melting of slags of various manganese and oxygen contents was shown. The separations found as a result of microscopic investigation agreed completely with the diagram obtained.

During the whole melting process samples of metal and slags were taken, as far as possible, from a number of Thomas meltings. The variations of the contents of the component elements of the iron during the melting process were discussed. The heavy fall of the constants of manganese contents is taken as an indication of the turning of the first acid slag into a basic one, which is the decisive factor for the metallurgical process based on this method. During the work of deoxidation the effect of the temperature of the added ferromanganese and the time of the meltings upon the progress and extent of deoxidation were ascertained. It was also found that there was a considerable loss of oxygen content during the solidification of the metal in the mould. All these factors were interpreted by means of the complete deoxidation diagram.

British Chemical Standard Alloy Steel "W 2."

Headquarters of British Chemical Standards announces a renewal of high-speed alloy steel "W," having the following standardised analysis:—

	%		%
Carbon	0.17–	Vanadium	0.82–
Silicon	0.14–	Tungsten	16.12–
Sulphur	0.051	Cobalt	4.35–
Phosphorus	0.026	Nickel	0.43–
Manganese	0.22–	Molybdenum	0.55–
Chromium	3.29–		

It will be noticed that in addition to the alloy elements which were in the original standard "W," the renewal contains molybdenum which now seems to be frequently used. The standard will be useful for checking all high-speed steel analyses, also cobalt magnet steels, chrome-molybdenum steels, etc.

The certificate of analysis, including an outline of the methods used, gives the analytical results of nine different chemists (one in Czechoslovakia, and one in Italy) representing independent analysts, a Government Department, steel manufacturers and motor-car makers—who are large users of high-speed steel.

A copy of the certificate is sent out with each bottle, which is sold in units of 25 grms., 50 grms., 100 grms. and 500 grms., at a price which it is estimated will eventually cover the cost of preparation.

Reviews of Current Publications.

Foundrywork and Metallurgy.

One of the disadvantages of many technical works dealing with the foundry has been the tendency of authors to allocate too much space to certain sections of the work in proportion to that dealing with other sections, with the result that books on foundry work are frequently unbalanced. The work in the foundry is so varied, and differs so much from other trades and industries, that it is difficult to cover the subject adequately in one book. The science of metallurgy has become definitely linked up with the art of moulding, and the castings now produced are more varied in their characteristics and meet a wider range of demand than formerly existed.

The need of a comprehensive work covering foundrywork and metallurgy has been appreciated for some time, and it was a happy thought of Sir Isaac Pitman and Sons, Ltd., to produce a work on this subject in a series of volumes. The work has been divided into appropriate sections, each of which has been written by an authority. The first four volumes, the last of which has just recently been published, are subdivided into thirteen sections.

The first volume deals with pattern-making, moulding, core-making, and machine moulding. The information given is of an elementary character, and we think the intricacy and importance of pattern-making could have been given more scope with advantage. The section on moulding and core-making gives the impression that the author has been somewhat limited to space, with the result that the work is rather disjointed. In machine moulding the advantages and disadvantages of compressed air and hydraulic pressure for power machines are discussed, but comparisons with electrically operated machines are omitted. Many moulding machines are illustrated. It is remarkable, however, that only French machines and machines of American design are shown: this may be an oversight. The line illustrations in this section dealing with pattern plates are very good, and are informative in themselves without the text.

The second volume deals with moulding materials and non-ferrous and ferrous metallurgy. Much depends upon the correct blending of materials used in moulding, and the author gives ample consideration to the subject. Fundamental metallurgical principles are not less important in the production of sound and useful castings and in the sections dealing with ferrous and non-ferrous metals and alloys considerable useful information is given. The author deals with the principles governing the cooling of pure metal, the range of binary alloys, and some more complicated systems in the non-ferrous field, while the use of the constitutional diagram is discussed.

Four subjects are discussed in the third volume which are of daily concern in the correct functioning of the foundry. These are refractories, cleaning castings, pyrometry, and foundry plant. A detailed consideration of the principles which should govern the choice of suitable refractories is admirably given. Useful information is also given regarding the most effective methods for dressing, trimming, and sand-blasting castings. To-day it is more fully recognised how much the appearance of castings influences repeat orders, and increasing attention is being directed to this subject. The section dealing with pyrometry, while admirably prepared, seems to be larger than it need be, and is greater than some of the other sections that offer relatively more scope. Of foundry plant, that necessary for handling the large amount of material involved in foundry work is of primary importance. Mechanical appliances for this purpose are discussed, but it is noticeable that the mono-rail trolley system, which is efficient in certain types of foundries, has been omitted. This section also deals with various appliances for mould and core drying, and the handling of moulds and castings.

The sections covered in volume four are metal melting, brass and bronze casting, and chilled cast iron for rolls. The influence of the melting plant and the conditions under which it is operated have an important bearing on the quality of metal in the resulting castings. The choice of melting processes is now very wide, and much useful data and information are given which will give readers a better appreciation of the advantages of different types of plant. Although fundamentally the principles involved in moulding are similar whatever the kind of casting, their application varies according to the metal used, and it is certainly profitable to include a section on brass and bronze castings. The production of chilled castings also is somewhat specialised, because of the difficult problems it entails, and in a work of this kind it could not readily be omitted.

Although we think the first volume somewhat weak, the other volumes more than compensate, and if the remaining volumes to be published are comparable with these, we shall have no hesitation in recommending the student, apprentice and young journeyman to procure the series. It should also prove to be of considerable value to the engineer, and executives in other departments, who have to deal with castings in one form or another, and whose lack of knowledge in regard to the production of castings is frequently a cause of trouble.

Edited by R. T. Rolfe, F.I.C.; published by Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, London, W.C. 2. Volumes I., II., II., and IV. Price 6s. net each.

Journal of Institute of Metals, Vol. XLVII.

Metallurgical Abstracts.

This volume of the Institute of Metals constitutes the first of the Abstracts Volumes to be issued in accordance with the new system of publication which came into force in January 1931. Its publication is a noteworthy departure from previous practice, as prior to 1931 the abstracts were published in half-yearly volumes together with a record of the proceedings of the Institute. Since the beginning of 1931, however, the abstracts have been published independently of the two half-yearly "Proceedings" volumes and issued monthly to members of the Institute. In order that these abstracts shall remain a permanent record and become generally available, they are now reissued as a substantial bound volume.

There can be no doubt that the departure from established practice by publishing abstracts of current metallurgical literature monthly has been much appreciated by members of the Institute, and this volume will be assured of a warm welcome. Now that it becomes available to all who have to consult metallurgical literature, the appreciation of the work involved and the service provided will be more widespread. The volume contains over 5,000 up-to-date summaries of papers and articles dealing with metallurgical subjects that have recently been published throughout the world.

Conveniently classified under twenty headings, the abstracts cover such subjects as properties of metals and alloys, corrosion, physical and mechanical testing, pyrometry, heat-treatment, working, foundry practice and appliances, and refractories and foundry materials. Reference to the immense mass of concise information thus rendered available is facilitated by a very full and complete "subject" and "name" index covering no fewer than 166 closely printed pages and containing over 20,000 references. How comprehensive is this index is suggested by the fact that nine pages of the subject index are devoted entirely to entries concerning aluminium and its alloys. With such a monumental reference volume at hand all concerned with metals—be they scientific investigators, makers of metals, or engineers—should find their work to be greatly facilitated.

Edited by G. Shaw Scott, M.Sc., F.C.I.S., and published by The Institute of Metals, 36, Victoria Street, Westminster, S.W. 1. Price £4, inclusive of two "Proceedings" volumes.

The Treatment of Metals by Magnetic Processes.

IN a lecture delivered before the Coventry Engineering Society on April 8, Mr. E. G. Herbert described the various stages by which he had arrived at his patent magnetic processes for the treatment of metals. Commencing with the discovery and the measurement of work-hardening capacity in hard steel by means of the pendulum, an investigation was made of the super-hardening which takes place under service conditions in motor-car gears and cams. This led to the invention of the Cloudburst process of steel-ball bombardment, which proved effective not only for producing an intensely hard surface, but also for revealing defects of hardness—soft spots, grinding troostite, and brittleness, which would generally escape observation by other methods of inspection. The discovery that superhardened steel has the remarkable property of age-hardening, a spontaneous increase of hardness continuing for several hours after the cessation of the Cloudburst bombardment, was the starting-point for a new series of researches, in the course of which it was found that the spontaneous after-hardening is not a simple change, but the first of a series of periodic hardness fluctuations consisting of alternating phases of hardening and softening, the periodicity of the fluctuations tending to increase until they finally damped out after an ageing period of many hours. Similar periodic fluctuations of hardness had been found to occur during the ageing of other metals after cold working, as for instance, in freshly-rolled brass, and they appeared to be a normal consequence of any severe atomic disturbance, occurring in freshly-quenched carbon steel, and after both primary and secondary heat treatments of high-speed steel. It had been found that when these fluctuations had damped out they could be started up afresh by rotating the metal in a strong magnetic field. This process was applicable, not only to steel, but also to non-ferrous and non-magnetic metals, and it was found that the cycle of periodic changes could be caused to repeat itself again and again by a repetition of the rotary magnetic treatment, while the metal could be "stabilised" at any selected phase of its hardness fluctuations by placing it for a short period in a constant magnetic field. This stabilising process was equally effective whether the fluctuations to which it was applied had been induced by thermal, mechanical, or magnetic disturbance of the structure.

The lecturer dwelt at some length on the probable implications of these interrelated phenomena. Recent experiments had indicated that in the hardness changes following the secondary heat treatment of high-speed steel, two entirely distinct and superimposed processes were involved—the austenite-martensite transformation familiar to metallurgists, which resulted in a net increase of hardness, and a periodic fluctuation arising from the rapid change from the condition of softness or low cohesion characteristic of hot metal to the condition of high cohesion in the cold metal. It was pointed out that two somewhat similar processes appeared to be involved in the age-hardening of duralumin, a steady increase of hardness due to precipitation, on which was superimposed a periodic fluctuation identical with that which occurred in steel, and due to the same cause—the sudden change from very low to relatively high cohesion which took place at the instant of quenching, the combined effect of the two processes being the well-known fluctuating rise of hardness during ageing.

The phenomenon of cohesion being an electro-magnetic attraction between the atoms—in magnetic and non-magnetic substances alike—and due in all cases to the revolving electrons which constituted circulating electric currents, it was scarcely surprising that the fluctuations of hardness—or, in other words, of cohesion—whether due, as had been suggested, to a gyroscopic precession, or some other cause, should be responsive to the influence of magnetism—as had been found to be the case in both magnetic and non-magnetic metals.

A further consideration here arose. Periodic hardness fluctuations, responsive to magnetic influence, had been found to be set up by such normal work-hardening processes as the rolling of brass or duralumin. The phenomenon of work-hardening had been generally associated with the lattice distortion which undoubtedly occurred when metal was deformed. In view of the recent experimental results, might it not be necessary to look for some factor in the phenomenon of work-hardening much deeper and more fundamental than lattice distortion—a change in the inter-atomic attraction which was the basis of cohesion, and therefore of hardness, strength, ductility, and other physical properties of metals.

The lecture concluded with a brief survey of the probable developments, both theoretical and practical, which might be anticipated as a result of these discoveries.

Catalogues and Other Publications.

Birmabright, Ltd., Dartmouth Road, Smethwick, near Birmingham, have sent us a copy of their recently issued booklet, which gives the latest data and useful information regarding their corrosion-resisting aluminium-alloy "Birmabright." This alloy has been the subject of official examination by Admiralty and Air Ministry Technical Departments, and Air Ministry specifications have been issued for the release of material for aircraft construction. It can be produced in the form of sand, die, and pressure castings; rolled sheets; extruded angles, rods and sections; drawn sections; extruded and drawn tubing; drawn wire; bolts and nuts; rivets; wood and metal screws; forgings and hot stampings, etc. Readers interested in "Birmabright" should obtain a copy of this excellently produced booklet in which its physical characteristics, manufacturing properties, corrosion resistance, as well as methods of treatment for preservation of surfaces are dealt with.

The properties and applications of bronzes containing nickel are outlined in the March issue of *The Nickel Bulletin*. The advantages possessed by these bronzes include resistance to corrosive media, improved wearing qualities, applicable for service at somewhat elevated temperatures, and possessing low coefficients of friction. This issue also contains a short article on nickel-alloy steels, which, together with the abstracts and references, forms an interesting and informative publication. A copy can be obtained on application to The Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W. 1.

George Sumner, Ltd., Rhodes Bank, Oldham, manufacture a patent twin-service steam valve, and a leaflet gives particulars about it, together with standard sizes and prices. These valves are built for pressures up to 225 lb. per sq. in., and temperatures up to 600° F. In the twin-service valve the seat and valve are reversible, which provides for a sound life at the initial cost of the valve.

The first number of the *Sulzer Technical Review for* 1932 contains a description of the Diesel-engine power-stations, steam boilers, air-humidifying and ventilating plant, tea-sorting equipment and heating installations, etc., supplied by the firm in recent years for use on tea plantations in the Dutch East Indies.

A further article is included on the application of super high-pressure gas-circulating pumps to hyper-compressor plants manufacturing synthetic ammonia, and a third article, illustrated with interesting diagrams, gives some new observations on the measurements of temperatures in Diesel engines.

We have received a folder from Henry Pels and Co., Ltd., London, N.W. 1, giving particulars of various types of shears, croppers, punches, and notchers, as well as presses. They suggest that the time is opportune for installing these machines when their cost is low.

Murex Welding Processes, Ltd., of Ferry Lane Works, Forest Road, London, N. 7, have sent us a brochure entitled "M.W.P. Welds Under the Microscope." Particulars are given of the microscopical examination and structure of weld metal as carried out in the M.W.P. laboratories. Photo-micrographs illustrate the effect upon the weld or deposited metal of adding various grades of flux coatings, or methods of applying the flux coating to one particular grade of wire core. This brochure is available on application.

Some Recent Inventions.

Improvements in Hard Alloys.

The carbides of metals of high melting point are known to be extraordinarily hard, some of them, such as, for instance, tungsten carbide, approaching very closely the hardness of diamond. It is carbides of this class that form the chief constituent of the materials which, under the designation of hard metals or hard metal alloys, are employed to an increasing extent in the manufacture of tools and implements.

A recent development in the production of hard alloys of this type consists in forming a hard alloy by sintering or melting a mixture of titanium carbide and titanium nitride. It is found, the inventors say, that an extraordinarily hard and at the same time, very solid product results which is very suitable for the manufacture of tools and working implements of every kind, but especially cutting tools. A special advantage of the new alloy consists in the fact that titanium compounds suitable for the production of titanium carbide and titanium nitride are available in large quantities as constituents of the slag obtained in the operation of blast-furnaces, so that the starting materials of the new alloy can be supplied very conveniently and cheaply. It is found to be particularly advantageous if the titanium carbide and titanium nitride are present in approximately equal quantities in the alloy. An alloy containing about 50% of titanium carbide and 50% titanium nitride has a melting point of about 3230° C., which is not only higher than that of titanium nitride, about 2950° C., and of titanium carbide, about 3140° C., but is actually the highest melting point obtainable within the series of possible alloys of titanium carbide and titanium nitride. It is probably this feature which is the cause of the particularly great hardness of an alloy consisting of 50% of titanium carbide and 50% of titanium nitride.

The new alloy can be produced by melting or by pressing and subsequent sintering or by simultaneous pressing and sintering of the starting materials in powder form. The toughness of the new alloy can be improved by adding one or more metals, such as cobalt, iron, or nickel, of lower melting point than the carbide and nitride forming the major portion of the alloy, the said metals being added in quantities up to a total of 25%.

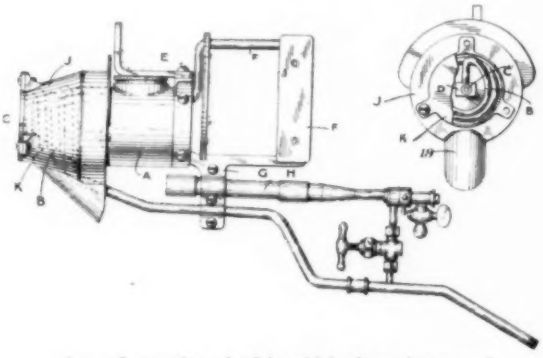
A suitable example of a method of production of the new alloy is as follows:—A powder mixture composed of 50% of titanium nitride and 50% of titanium carbide is taken. Pure titanium nitride can be produced by heating the commercial material for a short time in a tubular carbon furnace at 2000° C., while scavenging the furnace with nitrogen, and pure titanium carbide can be produced by heating a mixture of titanium acid and carbon for a short time in a current of hydrogen at 2000° C. Pressed bodies are formed of the mixture of the finely-powdered materials, and are sintered on a carbon bed at 2400° C., while being scavenged by nitrogen. Hereupon, they acquire a remarkable hardness. By the addition of a metal which it is relatively easy to melt—for instance, by the addition of from 7% to 10% cobalt—not only can the toughness of the finished alloy be improved, but also the sintering temperature is lowered. Furthermore, the pressed bodies may first be preliminarily sintered at a lower temperature than that necessary for final sintering, and then shaped, since in this condition they can easily be shaped. The great hardness and strength may then be imparted by final sintering.

365,895. Fried. Krupp Aktiengesellschaft, of Essen, Germany, patentees; Messrs. Gill, Jennings and Every-Clayton, agents, 51-52, Chancery Lane, London, W.C. 2. Accepted January 28, 1932.

Metal Spraying Pistols.

The accompanying illustrations refer to a recent development in metal-spraying pistols. The device comprises the employment of a conduit for the delivery of propelling fluid under pressure to the spraying nozzle, which is located in the path of the hot gases from the burner, and is of coiled formation. This preheating conduit ensures the thorough heating of the propelling fluid before its admission to the nozzle, with the result that the molten metal is not prematurely cooled as it flows to the nozzle and issues from it, and the efficiency of the pistol is claimed to be improved in consequence.

In addition, the pistol comprises a reservoir to contain a supply of hot spraying material, a spraying nozzle mounted on a frontal part of the reservoir, a shield-plate and a burner so arranged that its hot gases are directed along a wall of the reservoir and into the space between the shield plate and the front of the reservoir. The reservoir is a cylinder A, having a conical frontal part B. When the pistol is in use, the reservoir is disposed with its axis horizontal or somewhat inclined to the horizontal. At the point of the front part B is a spraying nozzle consisting of an inner part C and outer part D. In the top



A metal-spraying pistol in which air used to propel the metal is preheated.

of the reservoir, towards the rear, is a filling door E, through which the molten metal is introduced. The reservoir is mounted on a handle F, by which the pistol is held, and secured to this handle is a bracket G, by which a gas burner H is held. The axis of this burner is parallel to that of the reservoir, and it is so disposed as to direct hot gases along the bottom of the reservoir.

The shield-plate J acts as a deflector for hot gases from the burner and forms a circulating flue between it and the reservoir wall. The shield-plate also serves to screen the surface of an object being coated with metal by the pistol, from the hot gases of the burner and radiant heat of the reservoir. The spraying nozzle is supplied with air under pressure by way of a preheating coil K. This coil terminates in the outer portion of the nozzle where its axis is transverse to that of the nozzle.

The contents of the pistol is fed to the nozzle partly by gravity—the pistol being so held that the level of molten material in the reservoir is always above the nozzle—and partly by the ejector-action of the air issuing from the nozzle. Various modifications are possible in the design and construction of the pistol without departing from the spirit and scope of the design. Thus, for instance, means may be provided for maintaining the interior of the reservoir under super-atmospheric pressure in order to increase the ejector action of the spraying nozzle.

349,031. Reginald Caley, and Mellowes and Co., Ltd., both of Sheffield, patentees; Messrs. Boult, Wade and Tennant, agents, Hatton Garden, London, E.C. 1. Accepted May 19, 1931.

Business Notes and News

Nickel Products Increasing.

Despite the prevailing depression nickel products have more than retained their relative industrial position, largely as a result of new applications for nickel, monel metal, and the platinum metals, according to the annual report of the International Nickel Co. of Canada, Ltd., for 1931. The refinery products of this company, namely, nickel, copper, gold, silver, and the platinum metals, are supplemented by rolled malleable nickel and by "monel metal," together with other proprietary nickel-copper and chromium-nickel alloys.

Recent developments in the alloy-steel field have increased the use of nickel, special compositions of nickel cast iron have made considerable progress, while the more scientific use of nickel in electro deposition is making increasing demands for nickel anodes. The performance records of nickel-copper condenser tubes, containing 30% nickel, has resulted in further large installations, and the use of this alloy holds good promise. The corrosion resisting properties of monel metal, and such alloys as nickel silver and nickel-chromium steels, continue to meet the demands of the chemical and semi-chemical industries for materials of this character. The introduction of nickel-clad steel plate into several fields, such as storage tanks, evaporator bodies, chemical autoclaves, etc., is a new application. The rolled-steel plate, which is available in the usual dimensions, has a nickel coating on one or both sides, adequate in thickness to confer upon the nickel-clad plate many of the useful properties of pure nickel, but at substantially lower prices. The report views with confidence the prosperity of the nickel industry on the return of improved business conditions throughout the world.

New Marine Engine.

Much interest is being shown in a new type of marine engine now being erected conjointly by White's Engineering Co., Smith Dock Co., and Messrs. Hawthorn Leslie and Co., at Hebburn-on-Tyne. This engine is the invention of Mr. Albert White, who claims that it will save 30% in fuel, and an economy of 25% in weight at an initial cost of no more than that for the ordinary reciprocating engine. The engine is a combination of the turbine and reciprocating engine, and utilises two high-speed steam units connected to a separate propeller shaft through reduction gears. Construction of the engine is expected to progress far enough to enable bench tests to be made about the end of this month. It is to be tested at the St. Peter's Works of Messrs. Hawthorn, Leslie and Co., Ltd., Newcastle-on-Tyne.

International Aluminium Competition.

The first competition organised at the beginning of 1931 by the International Aluminium Bureau, with the object of finding and rewarding those inventions which promised further developments of the uses of aluminium and its alloys, met with considerable success in scientific and industrial circles. Over three hundred entries were submitted, and while no proposal was considered of sufficient merit to warrant the award of the special prize of 50,000 francs, the number containing novel ideas was sufficient to make the adjudication a difficult task.

Many competitors had not paid sufficient attention to the state of the metal market, and in consequence their proposals, though of interest technically, were not economic. Two proposals were considered to be of particular interest and possible of immediate application, and these were awarded the two prizes of 25,000 francs. They referred to entries dealing respectively with aluminium in the glove industry and the construction of central-heating radiators. The entry on the glove industry was submitted by Mr. C. Szmukler, Director of Megisseries Reynier, of Grenoble, is reproduced in a brochure, which also contains abstracts of other entries, including those by Mr. de Haes and Dr. Hampel on radiators, who shared the other prize of 25,000 francs.

The Bureau announces that as a result of the success of the first competition it has decided to organise this year a second international competition with prizes amounting to 100,000 francs. The rules of this competition are available on application to International Aluminium Bureau, 23 *bis*, Rue de Balzac, Paris, France; while helpful literature on the light alloys may be obtained from British Aluminium Co., Ltd., Adelaide House, King William Street, London, E.C. 4.

Shipbuilding Industry no Brighter.

No improvement in the shipbuilding industry is shown by the returns of the first quarter. There are few grounds for anticipating any appreciable revival, and unless a substantial number of orders are obtained within the next few months this year will prove to be the worst on record in regard to the construction of new ships. The condition of the shipbuilding industry in the whole country is emphasised by reference to the statement made by Commander Craven following the launch of H.M. Destroyer *Defender*, at the naval construction works of Messrs. Vickers-Armstrongs, Ltd., Barrow-in-Furness. When the *Queen of Bermuda* and H.M.S. *Porpoise*, which are under construction, are launched, the two shipyards of this company, at Barrow and Newcastle, comprising 23 berths, will be without a ship on the stocks if conditions remain as at present. It is of interest to note that this firm have representatives abroad negotiating for possible orders.

Despite the large over-supply of tonnage for existing needs it should be remembered that many vessels that have been laid up over long periods will be severely handicapped by the construction of more modern vessels, and in many instances it is questionable whether economical considerations will enable them to be profitably commissioned again. Sea transport has been quickened up considerably, and the British shipowner should take advantage of the prevailing low prices to replace vessels now out of date.

Pickling in Steel Production.

The use of acids in the various processes of manufacturing and rolling steel for the purpose of descaling or pickling the material should be controlled, said Mr. E. E. G. Bradbury, in a paper read before the Steel Rolling and Forging Society at Sheffield recently, in order to obtain maximum efficiency from the acid. The object of pickling is to remove scale formed in the hot-working of the steel during earlier operations, so that good, clean surfaces may be produced on subsequent working. Improvement in the use of acids is possible by standardising the pickling solution and by giving some indication of their useful life before replenishment is necessary. Deterioration of the solution results from evaporation as well as from use, and the right time to replenish or renew the solution is uncertain. Some system is also necessary to trap and condense the acid fumes so that they could be prevented from attacking machinery and steel passing through the works; they are also harmful to workmen. In some cases the action of inhibitors has proved beneficial in limiting the action of the acids to that necessary for the removal of scale; these are admirable in principle, and should be developed to make them practicable in every case. Attention should be given to the receptacles for the solutions and the bath should be scrupulously clean.

The pickling of steel is an example of how a process could be materially improved by the application of scientific knowledge, and by closer co-operation of the scientific and practical staffs.

New International Association for Testing Materials.

It is a matter for congratulation on the part of those interested in the work of the above Association that, since the Zurich Congress, Dr. W. Rosenhain, F.R.S., has been elected President of the Association for the ensuing period up to and including the next International Congress. It is of interest to note that the invitation extended by the British Committee to hold the next Congress in London in 1935 has been accepted by the Permanent Committee.

Personal.

The many friends of Mr. F. K. N Neath, B.Sc., will be interested to learn that he has resigned his position with the British Cast Iron Research Association, to join the Keighley Laboratories, Ltd., Keighley, Yorkshire—the well-known firm of metallurgists, analytical chemists and engineering consultants.

Mr. Neath has occupied an important position with the British Cast Iron Research Association for the past eight years, and is well known as the Honorary Secretary of the Birmingham, Coventry and West Midlands branch of the Institute of British Foundrymen, and was responsible for the organisation of the last annual conference of the Institute.

Some Contracts.

The Birtley Co., Ltd., Birtley, Durham, have received orders for dry-coal-cleaning plant from the Lambton, Hetton, and Joicey Collieries, Ltd., to treat 75 tons per hour at the Herrington Colliery; from Backworth Collieries, Ltd., for a central plant to treat 150 tons per hour at the Maud and Eccles pits; from the Ashington Coal Co., to treat 100 tons per hour at the Ashington Colliery; and from Pearson and Dorman Long, Ltd., for extensions to existing dry-coal-cleaning plant at Snowden Colliery (Kent).

Messrs. Lobnitz and Co., Renfrew, have received an order from the Soviet Government for the construction of a dredger for service at Leningrad Harbour. The value of this order is stated to be about £100,000.

The British Thomson-Houston Co., Ltd., Rugby, have received orders for control equipment for nine trolley omnibuses for the Tees-side Railless Traction Board, from Messrs. Ransomes, Sims, and Jefferies, Ltd., Ipswich; and from the Brush Electrical Engineering Co., Ltd., Loughborough, for eight cars for the Ilford Corporation Tramways.

The English Electric Co., of Preston, has secured a contract for the supply of two double deck four wheel trackless vehicles for the Southend-on-Sea Town Council.

Messrs. Stewarts and Lloyds, Ltd., of Glasgow and Birmingham, have secured a large part of the contract for 1,200 miles of oil piping for the Iraq Petroleum Co. The steel, as well as the pipes, will be manufactured in Stewarts and Lloyds ironworks. This contract is stated to be valued at approximately £500,000.

Henry Simon, Ltd., of Cheadle Heath, near Stockport, have received a contract from the London and North-Eastern Railway Co., for a belt coal-loading plant for the Royal Docks, Grimsby. This plant, which will have a total handling capacity of 1,600 tons of coal per hour, will include four sets of hydraulic-wagon tipplers to handle 20-ton coal wagons. The contract includes all the coal-handling machinery in the loading towers, as well as gantries to carry the lines of conveyers.

E. Cockey and Son, of Frome, have been awarded contracts for the erection of a gasometer and a large steel tank for the Frome Gas Co., and also a large gasometer for the Bristol Gas Co.

The Birmingham Railway Carriage and Wagon Co., Ltd., of Smethwick, have received a contract from the London and North-Eastern Railway Co. for 220 steel containers, each of 4 tons capacity.

Messrs. Dorman Long and Co., Ltd., Middlesbrough, have received contracts for 1,222 tons of steelwork for use in the construction of four bridges between Millers Dale and Buxton from the London, Midland and Scottish Railway Co.

Messrs. Redpath Brown and Co., Ltd., London, have received contracts for steelwork for many buildings, which are stated to cover a supply of about 1,800 tons of steel.

Standard Telephones and Cables have been awarded a contract by the Portuguese Government, stated to be of the value of £21,000, for the construction of a broadcasting station, with a strength of 20 kilowatts, at Barcarena, near Lisbon.

The Vaughan Crane Co., Ltd., Manchester, have obtained an order for the supply of a 120-ton four-motor overhead electric travelling crane for the Loch Tummel power-station included in the Grampian Electricity Scheme.

Henry Robb, Ltd., of Leith, have received an order from the Admiralty for a boom-defence ship similar to the *Moorgate*, which was launched last year by Bow, McLachlan and Co., Ltd., of Paisley.

Wm. Hamilton and Co. (1928), Ltd., Port Glasgow, have contracted to build a floating dock for the Crown Agents for the Colonies for service in South Africa. The length of the dock will be approximately 250 ft.

Messrs. Cowans, Sheldon and Co., of Carlisle, have received a contract from the Leith Dock Commissioners for four wharf cranes for the Imperial Dock at a cost of £10,000.

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ANTIMONY.

English	£42	0	0
Chinese	27	10	0
Crude	22	0	0

BRASS.

Solid Drawn Tubes	lb.	9½d.
Brazed Tubes	lb.	11¼d.
Rods Drawn	,,	8¼d.
Wire	,,	7¾d.
*Extruded Brass Bars	,,	4d.

COPPER.

Standard Cash	£30	0	0
Electrolytic	34	10	0
Best Selected	32	0	0
Tough	31	15	0
Sheets	62	10	0
Wire Bars	35	10	0
Ingot Bars	35	10	0
Solid Drawn Tubes	lb.	10d.	
Brazed Tubes	,,	10d.	

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	1	11½
‡Ferro Tungsten	,,	0	1	8½
		Plus 20%		
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2-4% Carbon, scale 12/- per unit	ton	36	12	0
NOMINAL: 4-6% Carbon, scale 8/- per unit	,,	27	10	0
NOMINAL: 6-8% Carbon, scale 8/- per unit	,,	24	15	0
NOMINAL: 8-10% Carbon, scale 8/- per unit	,,	24	10	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/6 per unit	,,	40	5	0
Guar. max. 1% Carbon, scale 15/- per unit	,,	43	0	0
§Guar. max. 0.7% Carbon, scale 15/- per unit	,,	54	2	6
‡Manganese Metal 96-98% Mn.	lb.	0	1	3
‡Metallic Chromium	,,	0	2	6
§‡Ferro-Vanadium 25-50%	,,	0	12	8
§Spiegel, 18-20%	ton	6	17	6
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	6	5	0
20/30% basis 25%, scale 3/6 per unit	,,	8	17	0
45/50% basis 45%, scale 5/- per unit	,,	12	12	6
70/80% basis 75%, scale 7/- per unit	,,	17	5	0
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	12	5	0
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
Ferro Phosphorus, 20-25%	ton	21	10	0

FUELS.

Foundry Coke—						
S. Wales	£1	2	6 to	1	7	6
Sheffield Export	0	18	0 to	0	18	6
Durham	0	14	6 to	0	15	0
Furnace Coke—						
Sheffield	0	12	0 to	0	12	6
S. Wales	0	17	6 to	0	18	0
Durham	0	14	0			

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)	£47	0	0
*Commercial Ingots	38	10	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	9½
*Cored Bars	,,	0	0	11½

LEAD.

Soft Foreign	£10	17	6
English	13	0	0

MANUFACTURED IRON.

Scotland—						
Crown Bars, Best	£10	5	0			
N.E. Coast—						
Rivets	11	0	0			
Best Bars	10	10	0			
Common Bars	10	0	0			
Lancashire—						
Crown Bars	9	15	0			
Hoops	£10	10	0 to	12	0	0
Midlands—						
Crown Bars	£9	15	0 to	10	0	0
Marked Bars	12	0	0			
Unmarked Bars	—					
Nut and Bolt Bars	£8	7	6 to	8	12	6
Gas Strip	10	12	6			
S. Yorks.—						
Best Bars	10	10	0			
Hoops	Hoops £10	10	0 to	12	0	0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	9½d.	
*Cored Bars	,,	11½d.	
†Strip	,,	10d.	
†Sheet to 10 W.G.	,,	10½d.	
†Wire	,,	12d.	
†Rods	,,	11d.	
†Tubes	,,	1/4½	
†Castings	,,	1/1½	

†10% Phos. Cop. £30 above B.S.
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†Phos. Tin (5%) £30 above English Ingots.

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Hematite M/Nos.	£3	8	6
Foundry No. 1	3	12	0
,, No. 3	3	9	6
N.E. Coast—			
Hematite No. 1	3	5	6
Foundry No. 1	3	1	0
,, No. 3	2	18	6
,, No. 4	2	17	6
Cleveland—			
Foundry No. 3	2	18	6
,, No. 4	2	17	6
Silicon Iron	3	1	0
Forge No. 4	2	17	0
N.W. Coast—			
Hematite	3	14	6
Midlands—			
N. Staffs Forge No. 4	3	1	0
,, Foundry No. 3	3	6	0
Northants—			
Forge No. 4	2	17	6
Foundry No. 3	3	2	6
Derbyshire Forge	3	1	0
,, Foundry No. 3	3	6	0
West Coast Hematite	4	3	6
East ,, ,,	3	4	6

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Billets	£12	18	0 to	£16	6	0
Wire Rods	£14	18	0 ,,	£17	17	6
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SCRAP METAL.

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,, Braziery	24	0	0			
,, Wire	—					
Brass	19	0	0			
Gun Metal	21	0	0			
Zinc	5	0	0			
Aluminium Cuttings	72	0	0			
Lead	9	0	0			
Heavy Steel—						
S. Wales	2	5	0			
Scotland	1	18	6			
Cleveland	1	15	0			
Cast Iron—						
Lancashire	2	0	0			
S. Wales	£2	2	6 to	2	5	0
Cleveland	£2	0	0 to	2	2	6
Steel Turnings—						
Cleveland	1	12	6			
Lancashire	1	2	6			
Cast Iron Borings—						
Cleveland	1	6	0			
Scotland	1	12	0			

SPELTER.

G.O.B. Official	—		
Hard	£9	10	0
English	11	10	0
India	11	5	0
Re-melted	9	10	0

STEEL.

Ship, Bridge, and Tank Plates—						
Scotland	£8	15	0			
North-East Coast	8	15	0			
Midlands	8	17	6			
Boiler Plates (Land), Scotland	9	0	0			
,, ,, (Marine) ,,	—					
,, ,, (Land), N.E. Coast	10	0	0			
,, ,, (Marine) ,,	10	10	0			
Angles, Scotland	8	7	6			
,, North-East Coast	8	7	6			
,, Midlands	8	7	6			
Joists	8	15	0			
Heavy Rails	8	10	0			
Fishplates	12	0	0			
Light Rails	£8	10	0 to	8	15	0
Sheffield—						
Siemens Acid Billets	9	2	6			
Hard Basic	£8	2	6 and	8	12	6
Medium Basic	£6	12	6 and	7	2	6
Soft Basic	6	0	0			
Hoops	£9	10	0 to	9	15	0
Manchester—						
Hoops	£9	0	0 to	10	0	0
Scotland, Sheets 24 B.G.	10	5	0			

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Round and Squares, ½ in. to ¼ in.	,,	3d.
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Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ⅜ in.	,,	3d.
,, ,, ½ in. × ¼ in.	,,	1/-

TIN.

Standard Cash	£107	0	0
English	108	5	0
Australian	108	5	0
Eastern	114	10	0
Tin Plates I.C. 20 × 14 box	0	16	0
Block Tin (Cash)	127	15	0

ZINC.

English Sheets	£23	10	0
Rods	27	0	0
Battery Plates	19	10	0

* McKechnie Brothers, Ltd., quoted April 9. † C. Clifford & Son, Ltd., quoted April 9. ‡ Murex Limited, quoted April 9

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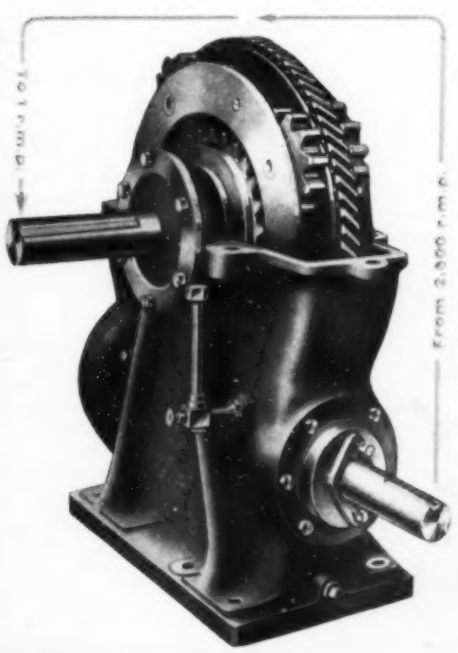

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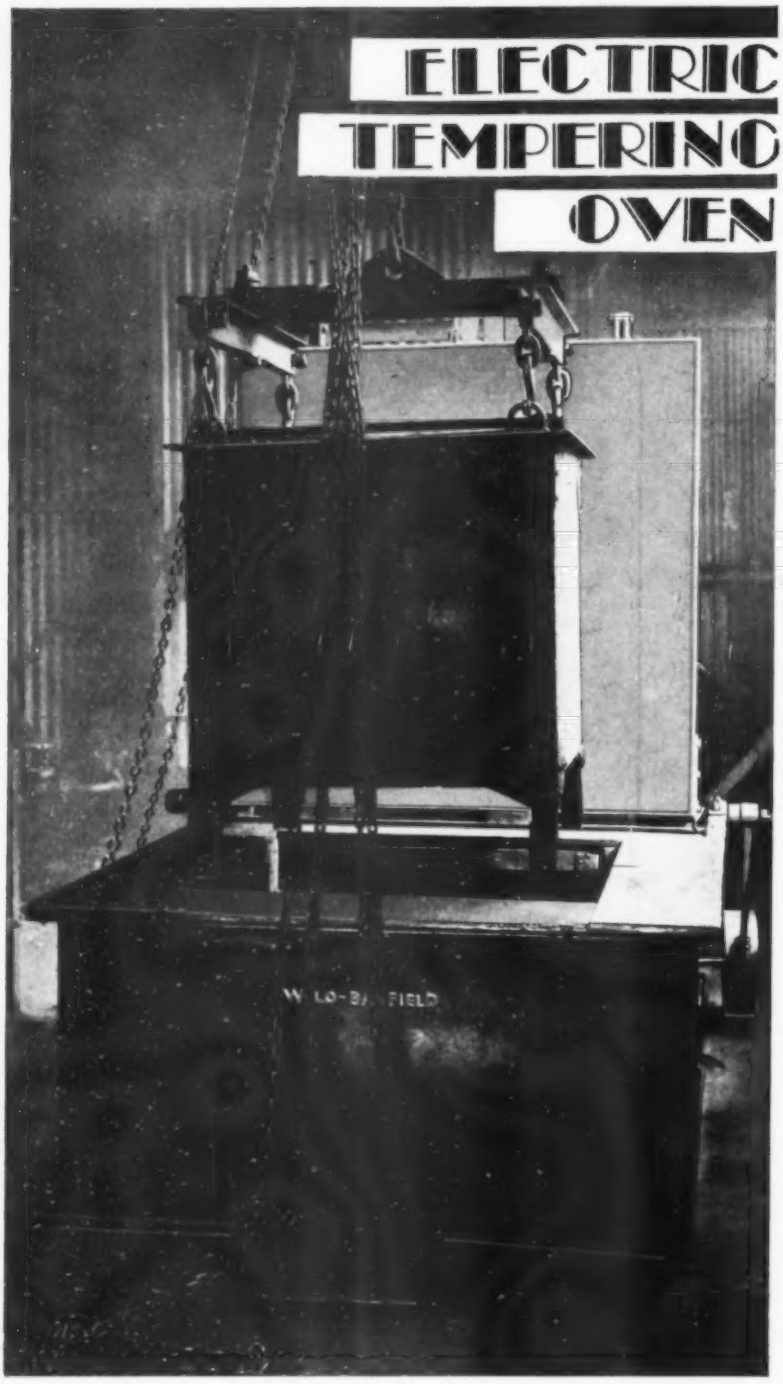
MANCHESTER: 511-13, Corn Exchange Buildings.
NEWCASTLE-ON-TYNE: 90, Pilgrim Street.
Smelting Works: WIDNES, Lancs.

ELECTRIC TEMPERING OVEN



PIT TYPE TEMPERING OVEN.

PROCESS. Tempering agricultural machinery components in forced air circulation.

CHAMBER. Charge container 3′ 4″ × 3′ 4″ × 3′ 4″ with patent centrifugal fan. (See below).

NORMAL OPERATING TEMPERATURE, 215° C.

POWER REQUIRED TO MAINTAIN 215° C., 1.7 k.w.

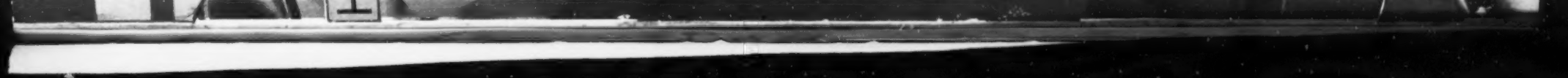
CONTROL. Single zone thermo-electric indicating controller.

METHOD OF HANDLING MATERIAL parts loaded in container, and lowered into chamber.

By aiding natural convection, this patent centrifugal fan increases the rate of heating of the charge and ensures even distribution of temperature throughout.

WILD-BARFIELD ELECTRIC FURNACES, LTD.

ELECFURN WORKS, NORTH ROAD, HOLLOWAY, LONDON, N. 7.

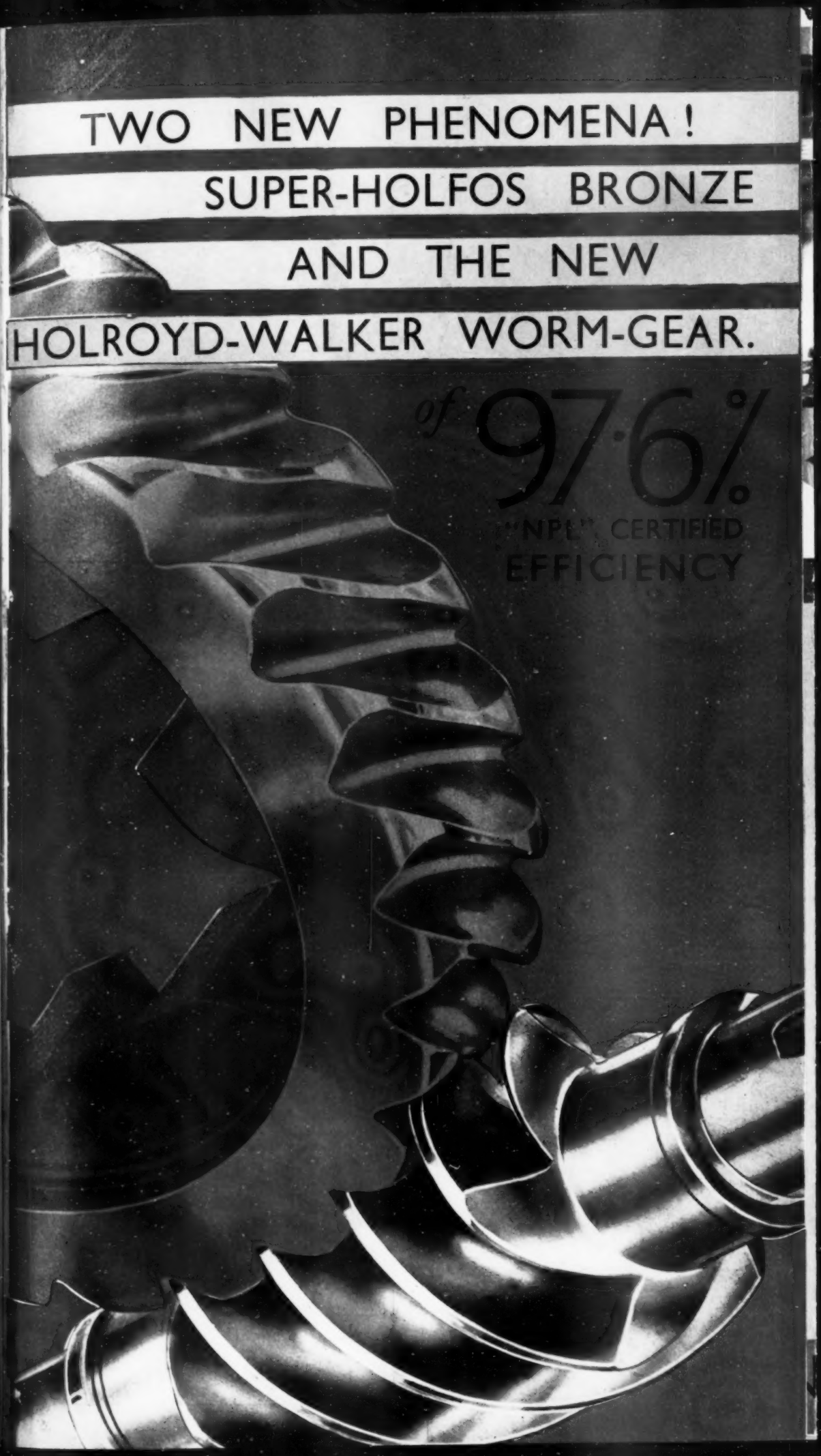


TWO NEW PHENOMENA!

SUPER-HOLFOS BRONZE

AND THE NEW

HOLROYD-WALKER WORM-GEAR.



Building *The* 97

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THE GREATER THE LOAD THE HIGHER THE EFFICIENCY.

INCREASE YOUR LOAD AND REDUCE YOUR CENTRES.

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MILNROW,

Worm-Gear Specialists.

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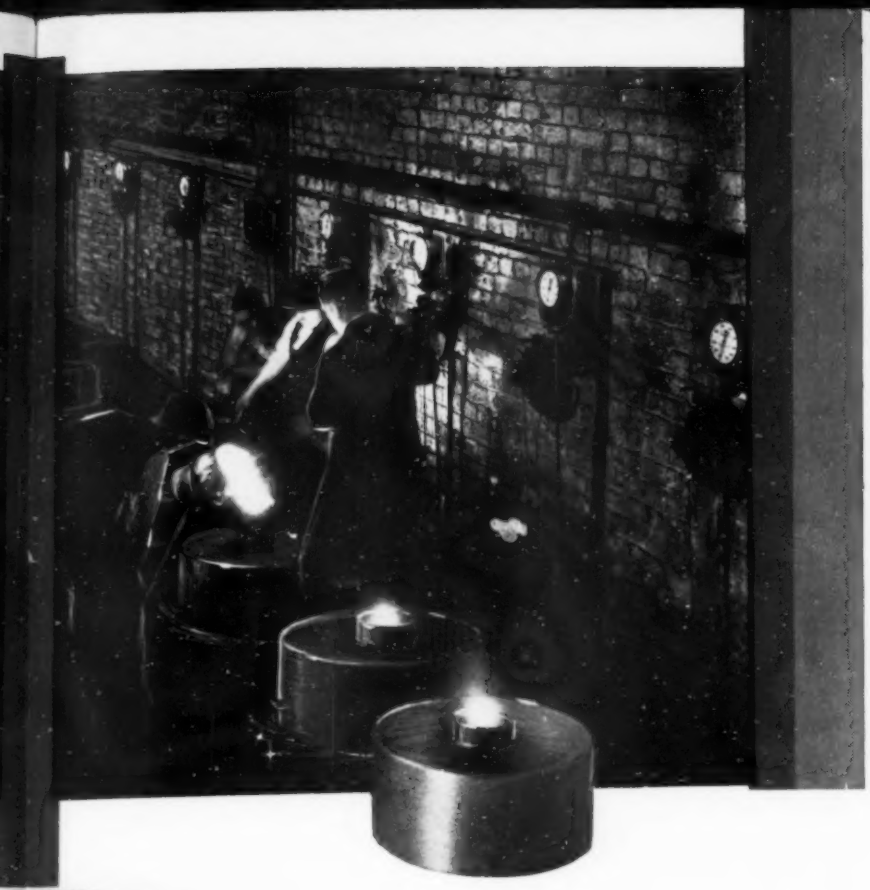
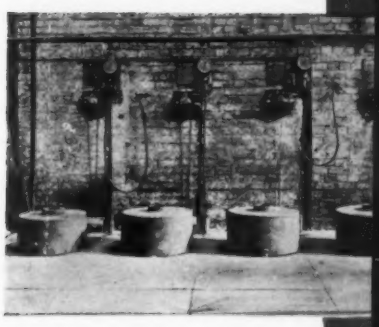




·6%
CIENCY

HOLROYD-WALKER WORM-GEAR.

This new engineering phenomenon, which has broken the World's Record in Worm-gear efficiency is the product of scientific tooth design, accurate manufacture, and correct selection and treatment of materials.

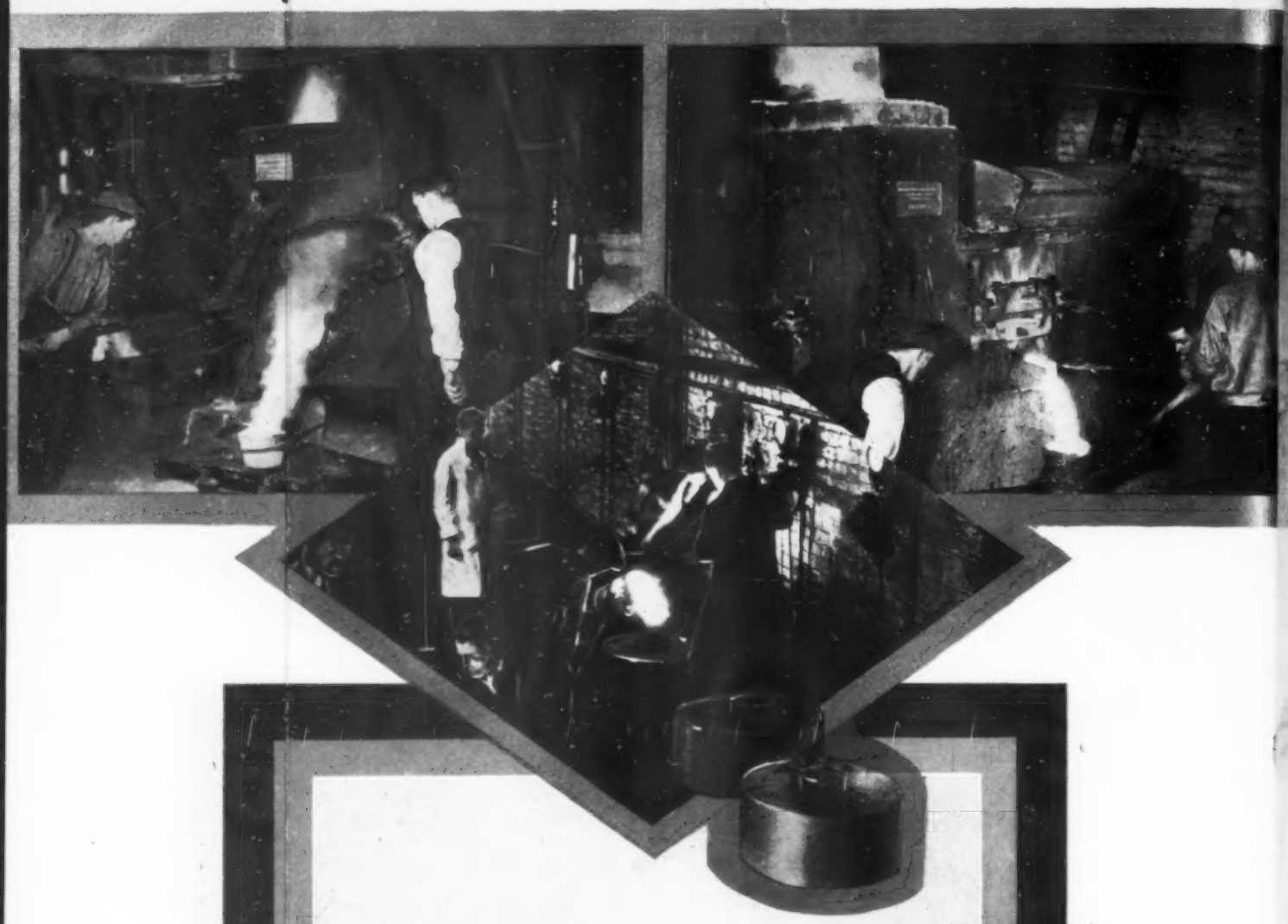
The Holroyd-Walker Gear embodies a new shape of tooth which sustains a permanent oil film between the worm and wheel. The greater the load, and the greater is the tenacity of the oil film. The National Physical Laboratory report shows that the efficiency is maintained under the heaviest of loads.

The maximum efficiency of the Holroyd-Walker Gear was 97.6% when transmitting 86 h.p. at 2,000 r.p.m. It is significant that the previous record of 97.3% was obtained when transmitting only 19 h.p. at 1,500 r.p.m.

This proves that the use of *the Holroyd-Walker tooth form* (provisionally-protected) and *Super-Holfos Bronze* gives a combination ahead of any other worm-gear product in the World.

LROYD & CO. LTD.
LANCS.

Makers of "Holfos" Bronze. Makers of Machine Tools to Increase Production.



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—*The* ***BRONZE*** *which made this remarkable record possible!*

SUPER-HOLFOS is the sequel development to our well-known HOLFOS Bronze. For many months we have experimented and conducted laboratory researches into the character of gear bronzes: SUPER-HOLFOS is the result.

Original HOLFOS owed its consistently-high quality to insistence upon careful metallurgical analysis of each "melt," and rigid observance of formula; to the latest melting methods, and a well-equipped modern foundry. The problem of producing SUPER-HOLFOS was that of the casting method and "control," because there is no particular secret about the metal ingredients, SUPER-HOLFOS being a straight Copper-Tin-Phosphorus Bronze.

SUPER-HOLFOS is cast centrifugally in machines of our own design. Speed rotation, rate of pouring, and temperature are controlled by instruments for EVERY cast.

We have established that difference in pouring speeds widely affects the finished result. SUPER-HOLFOS is guaranted to be perfectly homogeneous, and so "tight" in structure as to be the ideal material for gears, particularly worm-gears.

Inquire then for particulars and prices for castings of SUPER-HOLFOS, the bronze which made the remarkable efficiency of 97.6 % possible.

JOHN HOLROYD & CO., LTD.

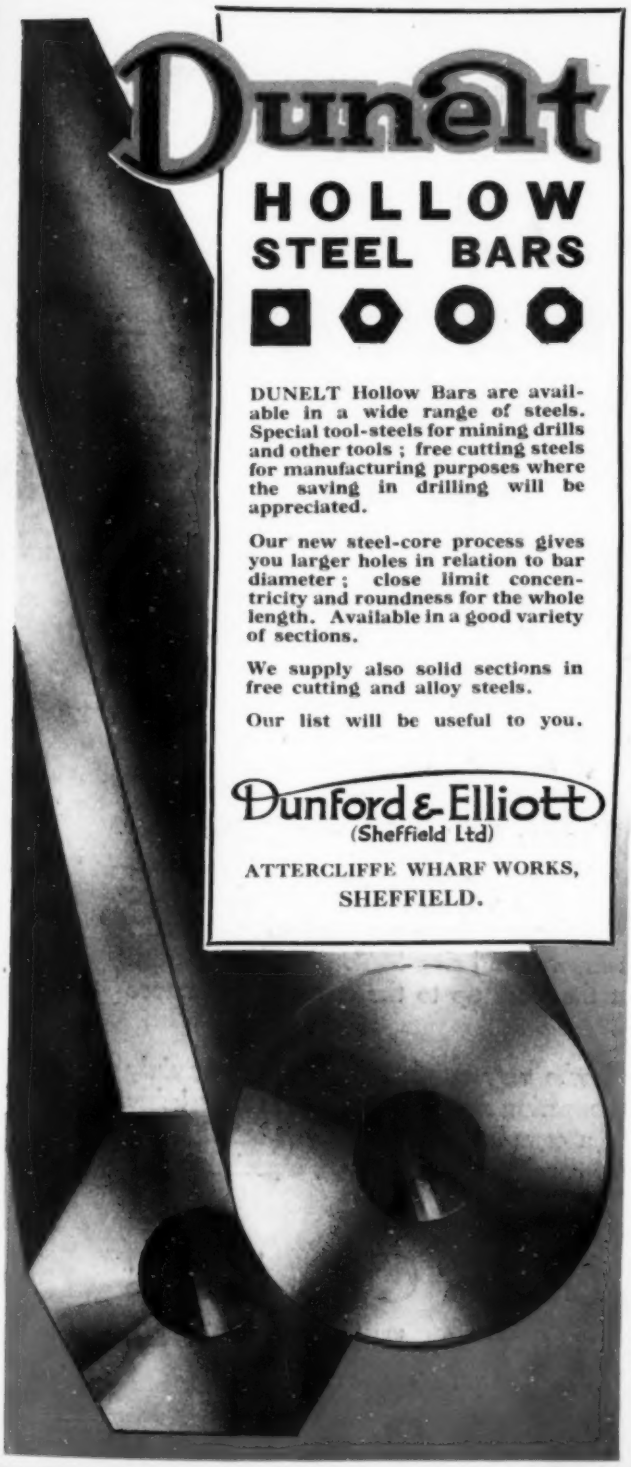
MILNROW. LANCS.

Bureau of Standards
DEC 31 1931

Vol. 5.—No. 26. DECEMBER, 1931. Price 2/-

METALLURGIA

THE BRITISH JOURNAL OF METALS.



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Our new steel-core process gives you larger holes in relation to bar diameter ; close limit concentricity and roundness for the whole length. Available in a good variety of sections.

We supply also solid sections in free cutting and alloy steels.

Our list will be useful to you.

Dunford & Elliott
(Sheffield Ltd)

ATTERCLIFFE WHARF WORKS,
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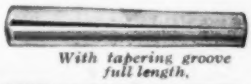
DRILL HOLE -and DRIVE HOME!

Test Mills' Grooved Pins in your own workshop. You will find it a profitable experiment. No tapping or reaming. Simply drill a hole—not necessarily to fine limits—and drive home the Pin. After exacting vibration tests the National Physical Laboratory, Teddington, reports that Mills' Grooved Pins give greater security than set pins, dowels, or taper pins of the old type. The economy in tools and labour costs is also considerable. Please write for a free sample supply of Grooved Pins and make a thorough test. They will certainly help to cut your production costs.

GROOVED STUDS.
A rigid fixing for name plates, instruction plates, etc., Drill a hole and hammer in.



With tapering groove full length.

With tapering groove half length.

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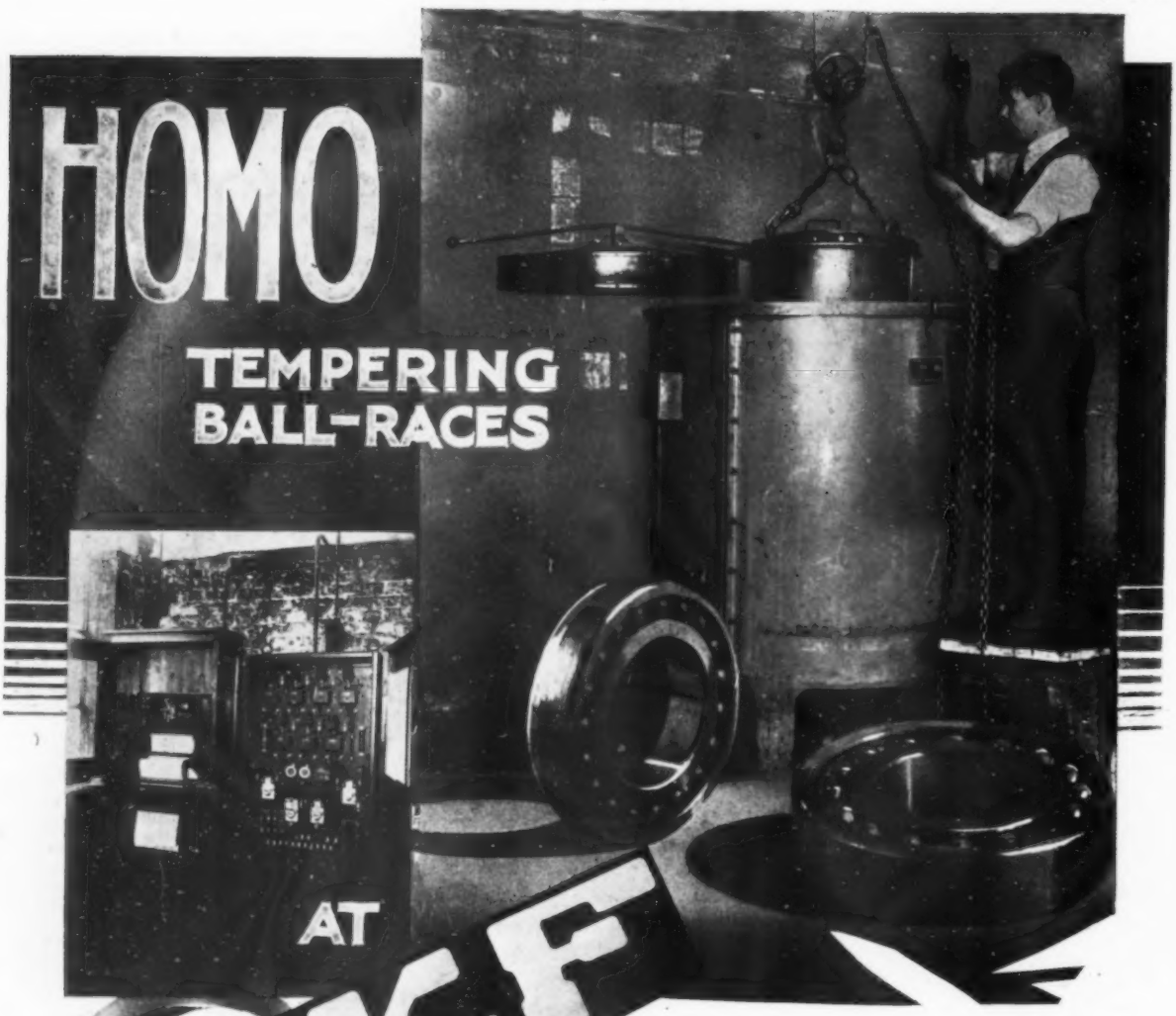
Exors. of JAMES MILLS, LTD., BREDBURY, Nr. STOCKPORT.



Who say:

"The HOMO Furnace illustrated is part of the equipment used here for tempering ball-bearing races. The load consists of approximately 4 cwts. of rings of various sizes. The rings in the Furnace have a period of one hour, the maximum temperature being 350°. It takes approx. 25 mins. to heat the work up to the control temperature (350° F.).

"The Furnace works very satisfactorily, and is certainly an ideal way of tempering rings, since it affords remarkably fine control, and a complete record of the whole heating cycle, which is of considerable advantage, especially when working throughout day and night."

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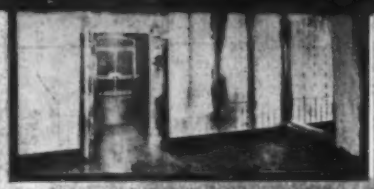
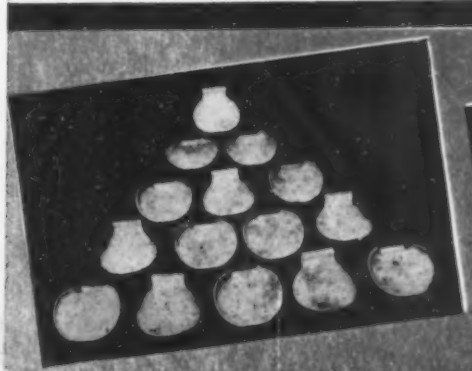
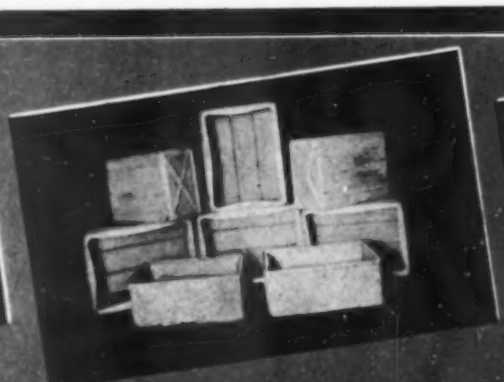
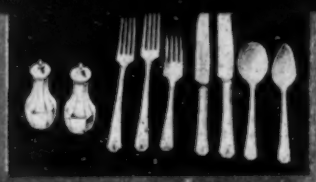
IMMACULATE STAINLESS STEEL

English Steel Corporation Ltd.

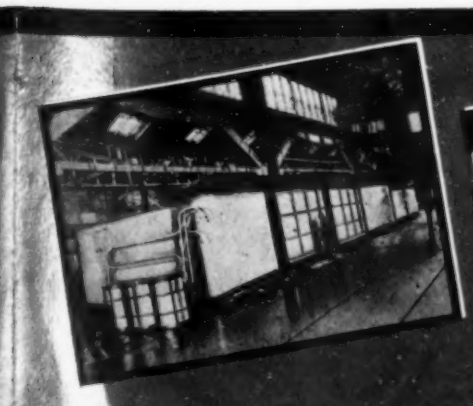
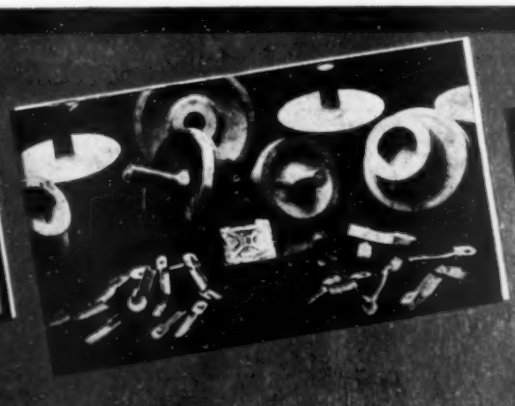
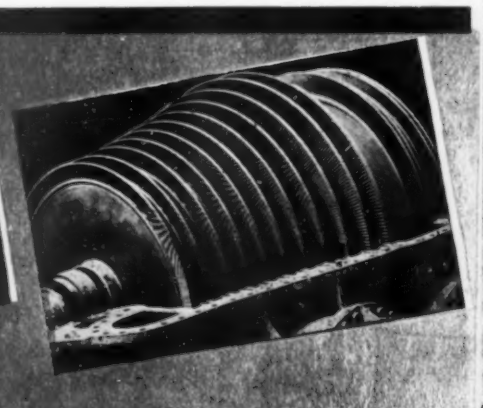


Material.	English Steel Corporation Symbol.	Equivalent BESA—or Air Ministry Specification Nos.	Analysis. Carbon. Min.	Carbon. Max.	Silicon. Min.	Silicon. Max.	Manganese Min.	Manganese Max.	Nickel. Min.	Nickel. Max.	Chromium. Min.	Chromium. Max.	Molybdenum. Min.	Molybdenum. Max.	Method of Heat Treatment.
Stainless Chromium Steel	**IMMAC-ULATE 1**	(S 61) DTD 23B, 39, 46A, 53, 97, 102, 105	—	0.15	—	0.50	—	—	—	1.00	12.00	—	—	—	Air, Oil, or Water-treated
Stainless Chromium Steel	**IMMAC-ULATE 2**	(S 62) DTD 46A	0.16	0.35	—	0.50	—	—	—	1.00	12.00	—	—	—	Air, Oil, or Water-treated
Stainless Nickel Chromium Steel..	**IMMAC-ULATE 3**	DTD 24A 42, 43, 57A	0.10	0.15	—	1.00	—	0.50	9.50	10.50	15.00	17.00	—	—	Normalised Water-treated
Stainless Nickel-Chromium Steel..	**IMMAC-ULATE 4**	DTD 24A 42, 43, 57A	0.15	0.30	—	1.00	—	0.50	6.00	8.00	18.00	22.00	—	—	Normalised Normalised
Stainless and Heat-resisting Nickel-Chromium Steel	**IMMAC-ULATE 5**	DTD 61	0.35	0.45	2.00	3.00	1.00	1.50	24.00	26.00	18.00	22.00	—	—	Normalised
Stainless and Heat-resisting Nickel-Chromium Tungsten Steel	**IMMAC-ULATE 6**	DTD 49A	0.35	0.45	1.50	2.50	1.00	1.50	25.00	30.00	14.00	16.00	TUNGSTEN 4.00		Normalised
High Chromium Non-Corrosive Steel	**IMMAC-ULATE 7**	DTD 60A DTD 146 S 80	0.15	0.25	0.30	0.60	0.40	1.00	1.50	2.50	17.00	19.00	—	—	Air or Oil Treated
Heat-resisting Nickel-Chromium Tungsten Steel	**IMMAC-ULATE 9**	DTD 49A	0.40	0.50	1.20	1.50	0.50	0.60	10.00	12.00	12.00	14.00	TUNGSTEN 2.00	2.50	Normalised
Stainless and Heat-resisting Nickel-Chromium Alloy	**VIKRO**		—	1.00	0.50	1.00	—	1.00	63.00	65.00	13.00	23.00	—	—	Normalised
Stainless and Heat-resisting Chromium Alloy	**PYRISTA**		—	2.50	—	2.50	—	1.50	—	2.00	26.00	29.00	—	—	



Heat Treatment Degrees Centigrade.				Mechanical Tests on Bars 1¼ in. Diameter at time of Heat Treatment.								English Steel Corporation Symbol	Characteristics and Applications.
				Tensile Test.									
Forge.	Normalise	Harden	Temper (approx.)	Yield Stress Tons Sq. In. Min.	Maximum Stress Tons Sq. In. Min.	Maximum Stress Tons Sq. In. Max.	Elongation % Min.	Reduction of Area % Min.	Izod. Impact Test Ft. Lb. Min.	Brinell Hardness Test 3,000 kg. 10 m/m. dia. Ball. Min.	Brinell Hardness Test 3,000 kg. 10 m/m. dia. Ball. Max.		
1100 to 1150	—	940	600/750	—	35	45	25	50	25/45	152	207	**IMMAC-ULATE 1**	Valves, Golf Clubs, Ships' fittings, Tubes, Fittings or Chemical Work, Pipes and fittings, Turbine Blades.
1100 to 1150	—	940	600/750	—	46	52	20	45	20/35	207	235	**IMMAC-ULATE 2**	Cutlery, Tools, Valves, Ball and Roller Bearings, Ships' Propellers.
Minimum 950	1050	—	—	12	35	45	50	55	75	150	180	**IMMAC-ULATE 3**	For resisting atmospheric corrosion and certain dilute acids. Can be rolled into thin Sheets and deeply pressed, drawn into Tubes, etc.
Minimum 950	—	1050	—	15	35	45	50	55	75	150	180		
Minimum 950	1150	—	—	20	45	55	40	50	50	170	200	**IMMAC-ULATE 4**	Similar to IMMACULATE 3, but higher in tensile strength.
Minimum 950	850	—	—	27	50	60	30	30	30	200	250		
Minimum 950	850	—	—	25	45	55	30	45	40	190	240	**IMMAC-ULATE 5**	For use at high temperatures. Resistance to furnace gases, atmospheric corrosion, weak and certain strong acids.
Minimum 950	850	—	—	35	50	65	20	40	30	200	260	**IMMAC-ULATE 6**	For use at high temperatures. Similar to IMMACULATE 5, but with slightly more resistance to intergranular cracking.
Minimum 950	—	950	500/750	35	50	75	23	55	45	220	350	**IMMAC-ULATE 7**	Possesses greater resistance to corrosion than IMMACULATES 1 and 2, and is much less liable to electrolitic attack when working in contact with Copper Alloys, as in Propellers, Shafts, etc. In addition has better mechanical properties as regards resistance to fatigue.
Minimum 950	—	—	—	35	60	68	22	35	35	277	311	**IMMAC-ULATE 9**	Exhaust valves for petrol and oil engines, and similar applications.
	850	—	—	35	50	60	15	25	—	180	240	**VIKRO**	For strength and resistance to oxidation at high temperatures. Case Hardening Boxes, Furnaces, Baffle-plates, etc.
—	—	—	—	—	—	—	—	—	—	—	—	**PYRISTA**	Excellent Heat Resisting Steel, but somewhat brittle. Particularly suitable for use in sulphurous atmospheres.

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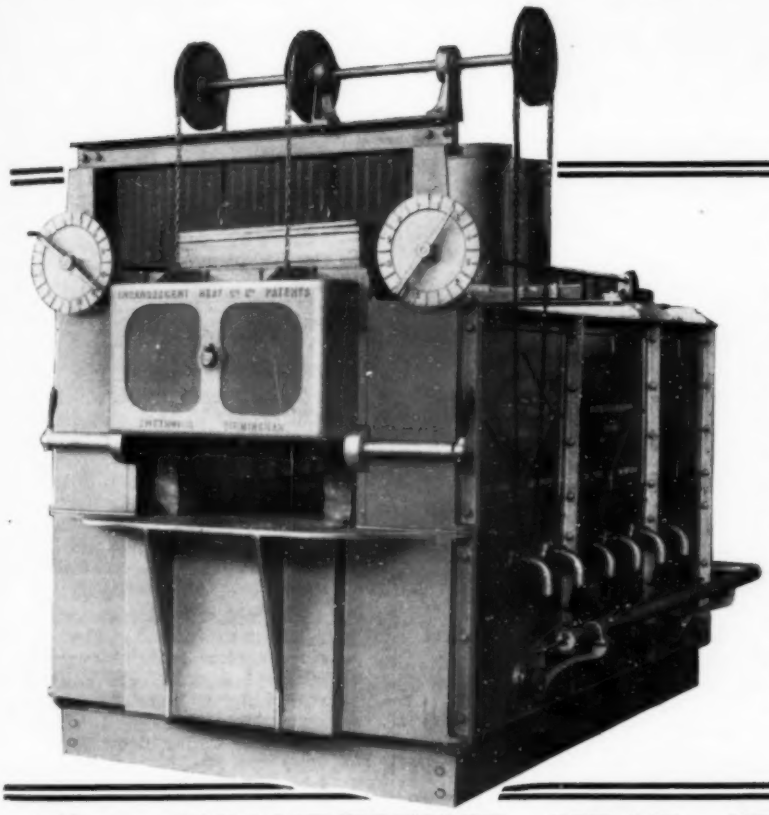

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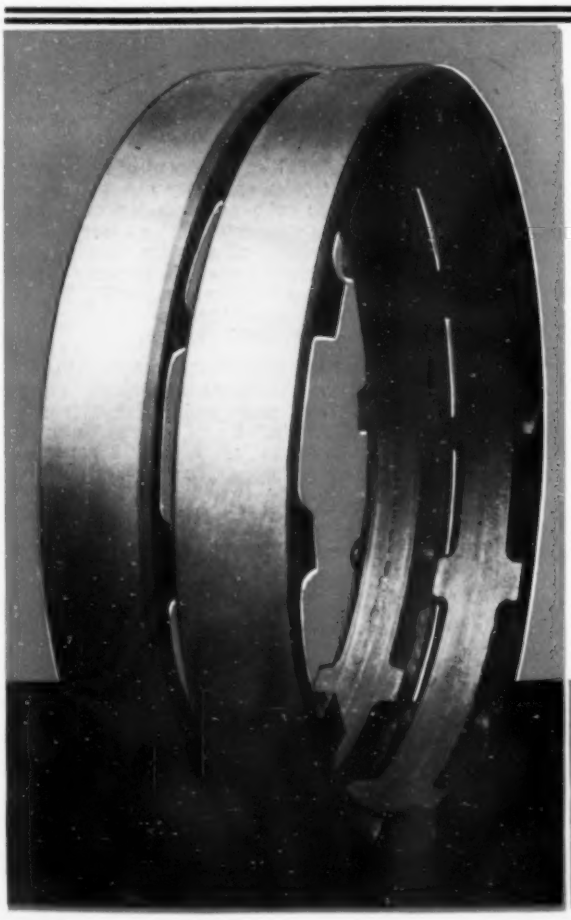
'Phone: Sloan 7803. 'Grams: Incandheat, Knights, London. Telephone: City 2953. Telegrams: Selasgas, Manchester.



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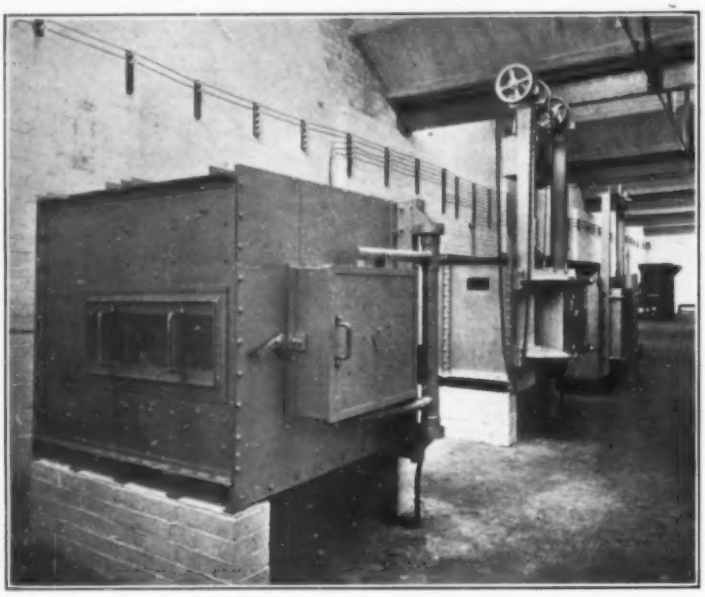

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Methods and Costs of Concentrating Tungsten Ores at Atolia.

The methods and costs of concentrating scheelite, as practised in two mills of the Atolia Mining Co., California, has been prepared by W. O. Vanderburg, of the United States Bureau of Mines. The Atolia Mining Co. operates two concentrators one of 800 tons daily capacity, for recovering scheelite (calcium tungstate) contained in placer material, and the other, of 150 tons daily capacity, for the treatment of scheelite ore.

The placer material, which averages a little over 1½ lb. of scheelite per ton, is mined by a revolving type shovel and passed through a grizzly with 6-in. spaces. The undersize is reduced to 2-in. size by a swing-hammer disintegrator. The minus 2-in. material is concentrated in jigs which produce concentrates, hutch, and tailings. The hutch is cleaned on tables.

The concentration ration averages 1,369 tons into 1; the combined concentrates contain approximately 62% of tungstic oxide, 0·01% of phosphorus; the recovery of scheelite amounts to about 70%. The cost of concentrating for 10 months of the year 1930 was $0·37 per ton of material treated.

The mill for the treatment of ore operated last in 1929 on dump material, which contained about 6 lb. of scheelite per ton. The treatment of this material was much the same as the treatment of placer material except that the ore, after the removal of waste by sorting, was reduced by crushing to ¾-in. size. The minus ½-in. material was sized by screens; the oversize was treated by jigs, and the undersize, combined with jig hutch, was concentrated on tables.

In the treatment of ore the concentration ratio was about 400 tons into 1; the concentrates contained approximately 67% of tungstic oxides, 0·45% of sulphur, and 0·075% of phosphorous; the recovery of scheelite amounted to about 80%. The cost of concentrating ore for the year 1929 was $1·22 per ton.

Further details are given in Information Circular 6532, "Methods and Costs of Concentrating Tungsten Ores at Atolia," issued by the United States Bureau of Mines, Department of Commerce, Washington, D.C.

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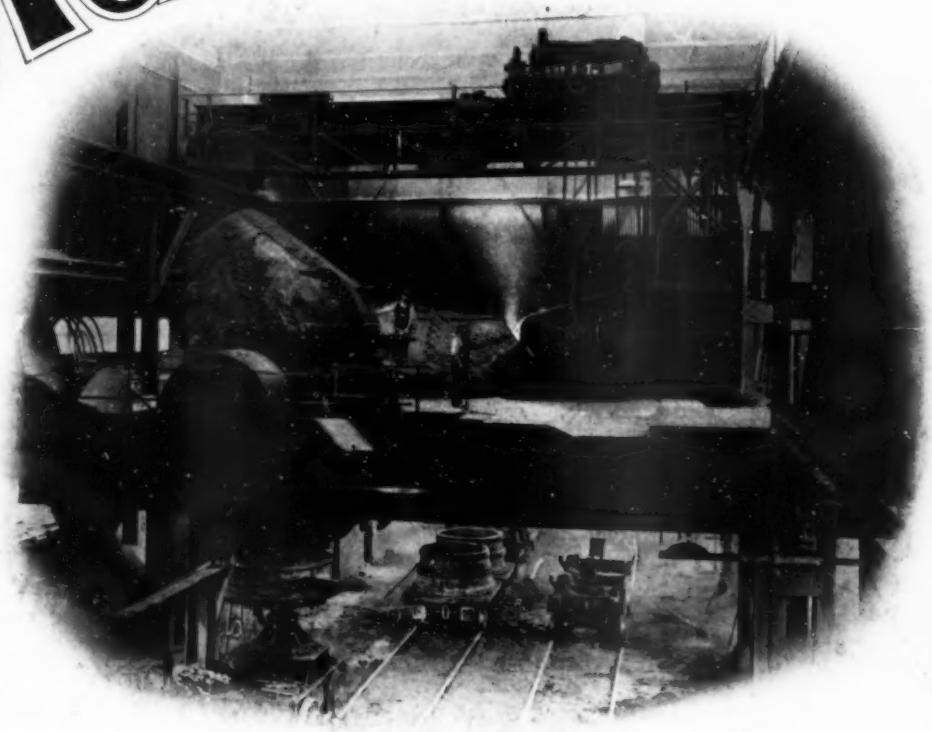

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up to 200 tons capacity
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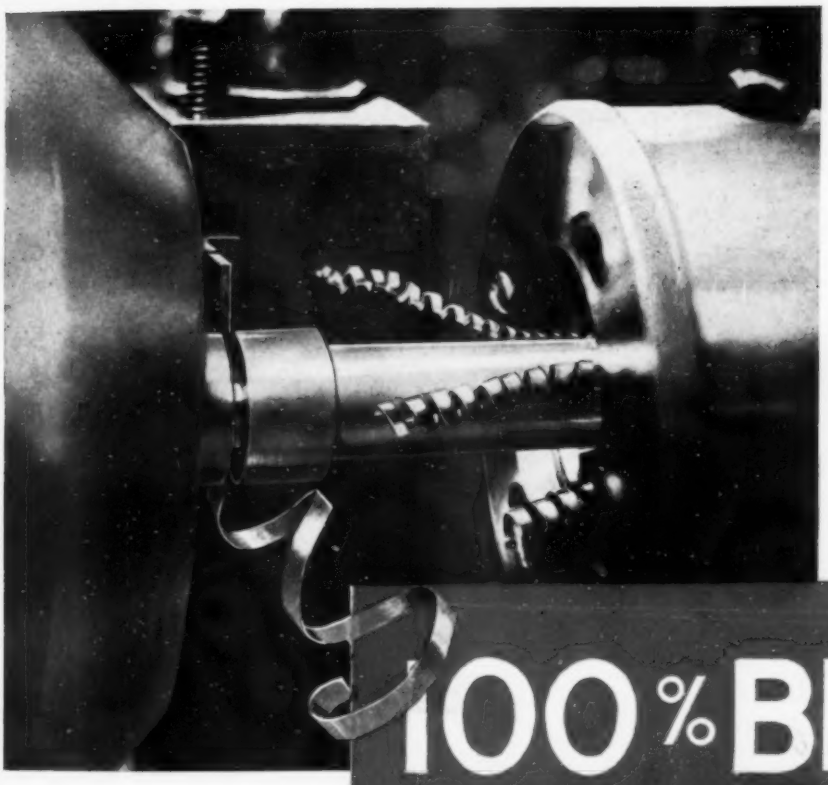

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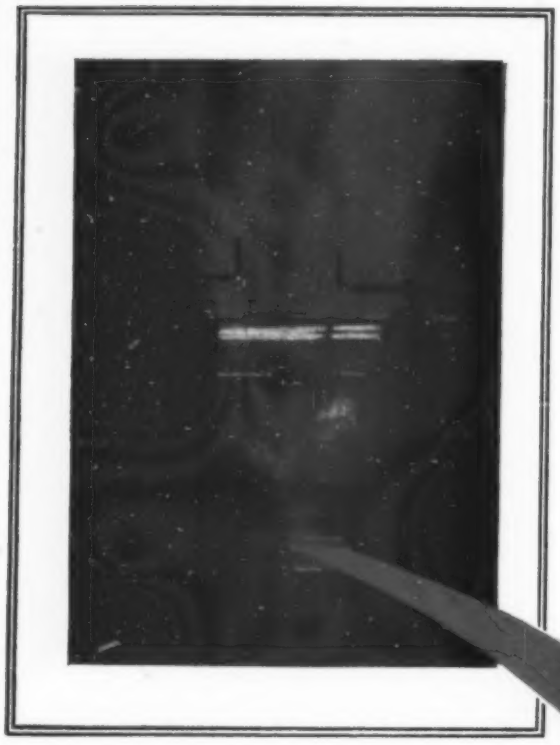

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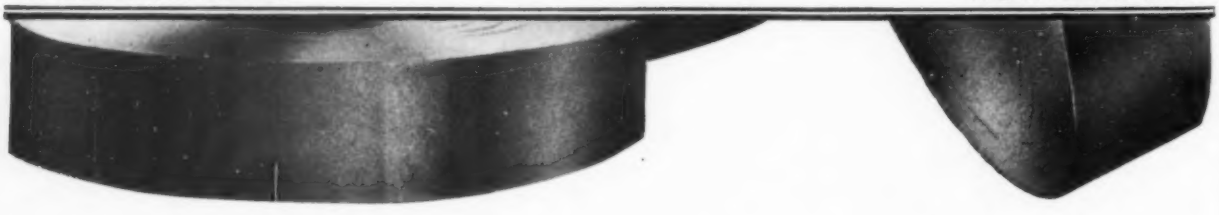

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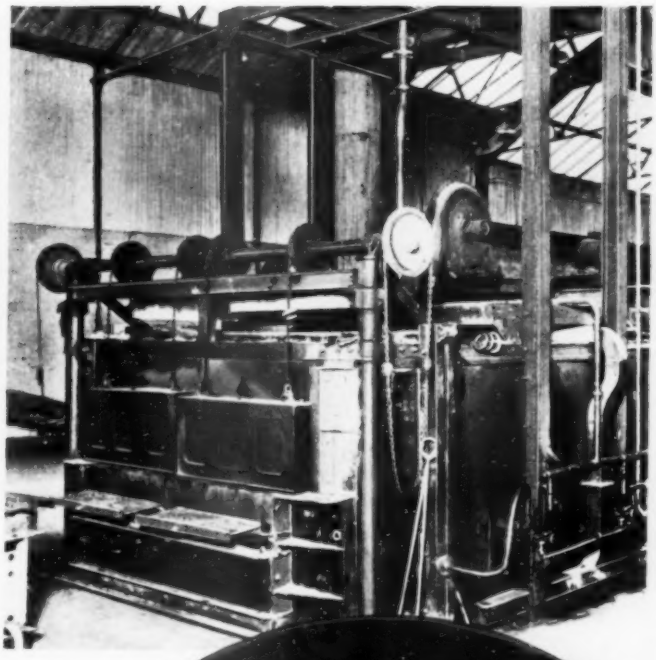

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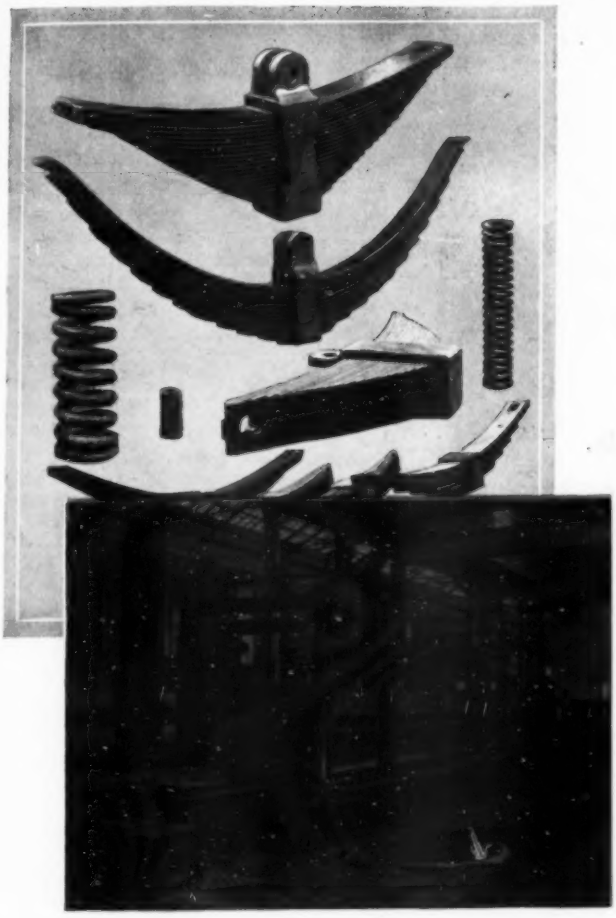

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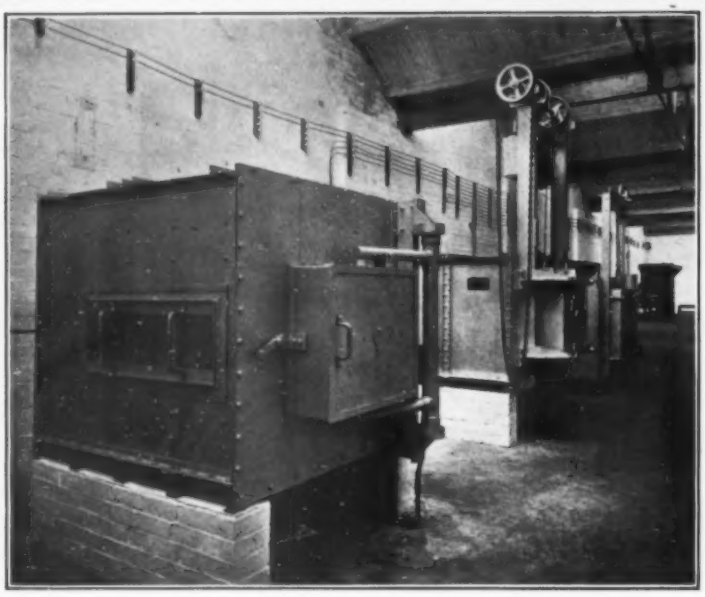

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The Influence of Antimony on Aluminium Alloys.

ONE of the greatest obstacles to a wider use of light alloys in construction in general, particularly in marine construction and in the machinery and equipment of the chemical industry, is the small resistance of such alloys to the corrosive action of hot water, acid, or alkaline liquids or vapours, salt air, sea water, etc. Although to a considerable extent this has been mitigated, so far as practical application goes, many problems still require to be solved.

Intensive research has been carried out with the object of trying to produce a light metal which would have good mechanical characteristics, accompanied by an efficaceous and permanent corrosion resistance; one of the lines of attack of the problem has been that of mechanically plating, by an ingenious technical process, aluminium of high purity and corrosion resistance to an alloy of aluminium having very high physico-mechanical qualities. From this might result an ideal metal, but there are certain disadvantages inherent to a plated material.

The subject is discussed in a long and interesting article by A. W. Bonaretti, the editor of *Metalli Leggeri Loro Applicazioni*, a full translation of which is given in "Light Metals Research," vol. ii, No. 2, published by the British Aluminium Co., Ltd.

In his paper, Signor Bonaretti first discusses corrosion problems and the possible methods of protection, particularly in reference to corrosion by sea-water, which is at the same time the most common and the most devastating corrosive enemy. He then proceeds to review the behaviour of the ordinary aluminium alloys to sea-water before passing to the quaternary alloys of Al-Mn-Mg-Sb, which he deals with in detail. The third section of the article is devoted to general considerations of protective measures against corrosion for the light alloys. The final part of the article gives brief indications of the special technique which should be observed in working alloys of the K.S. Seewasser type.

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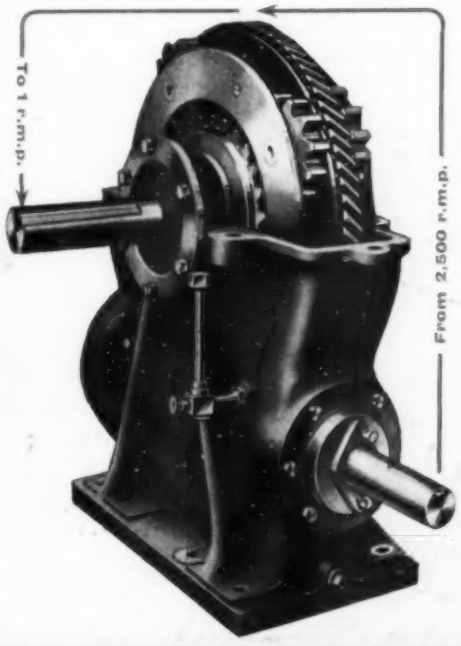

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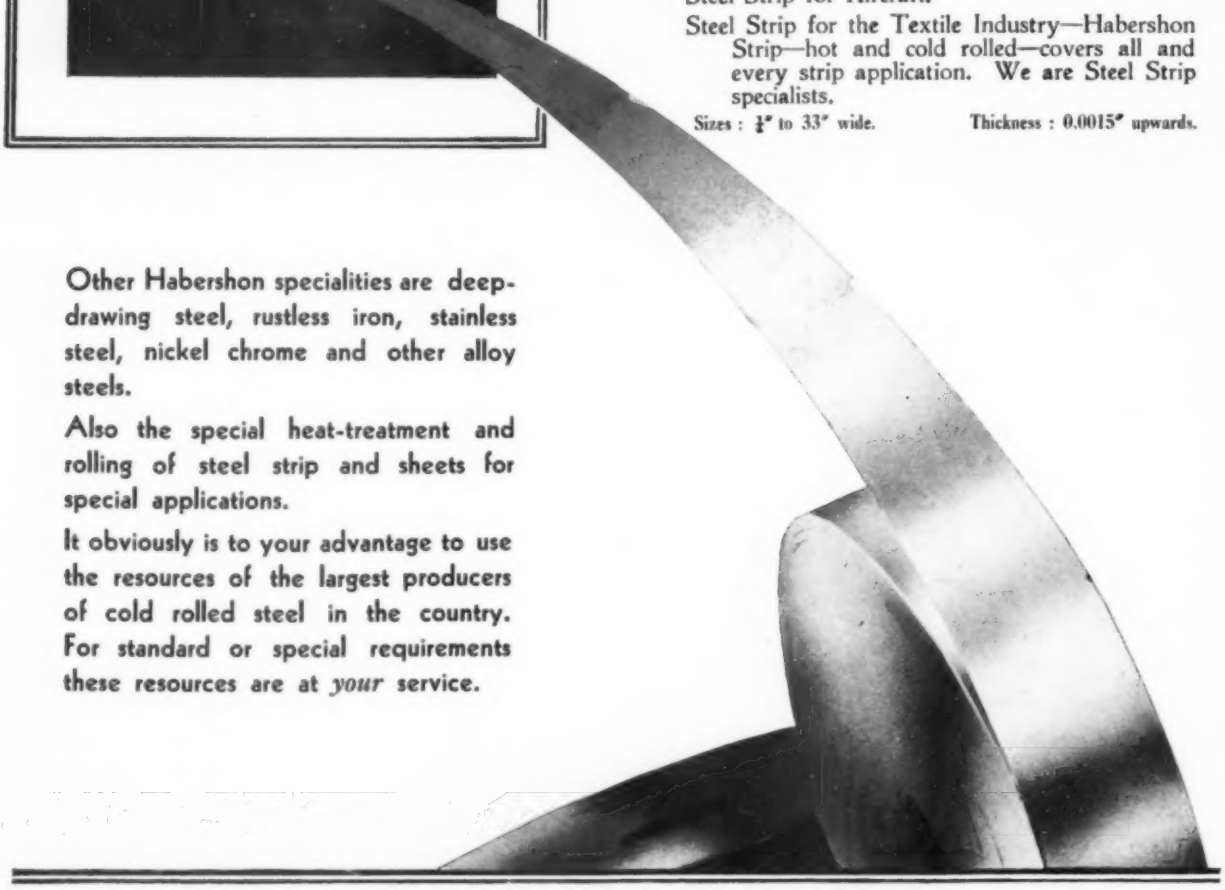

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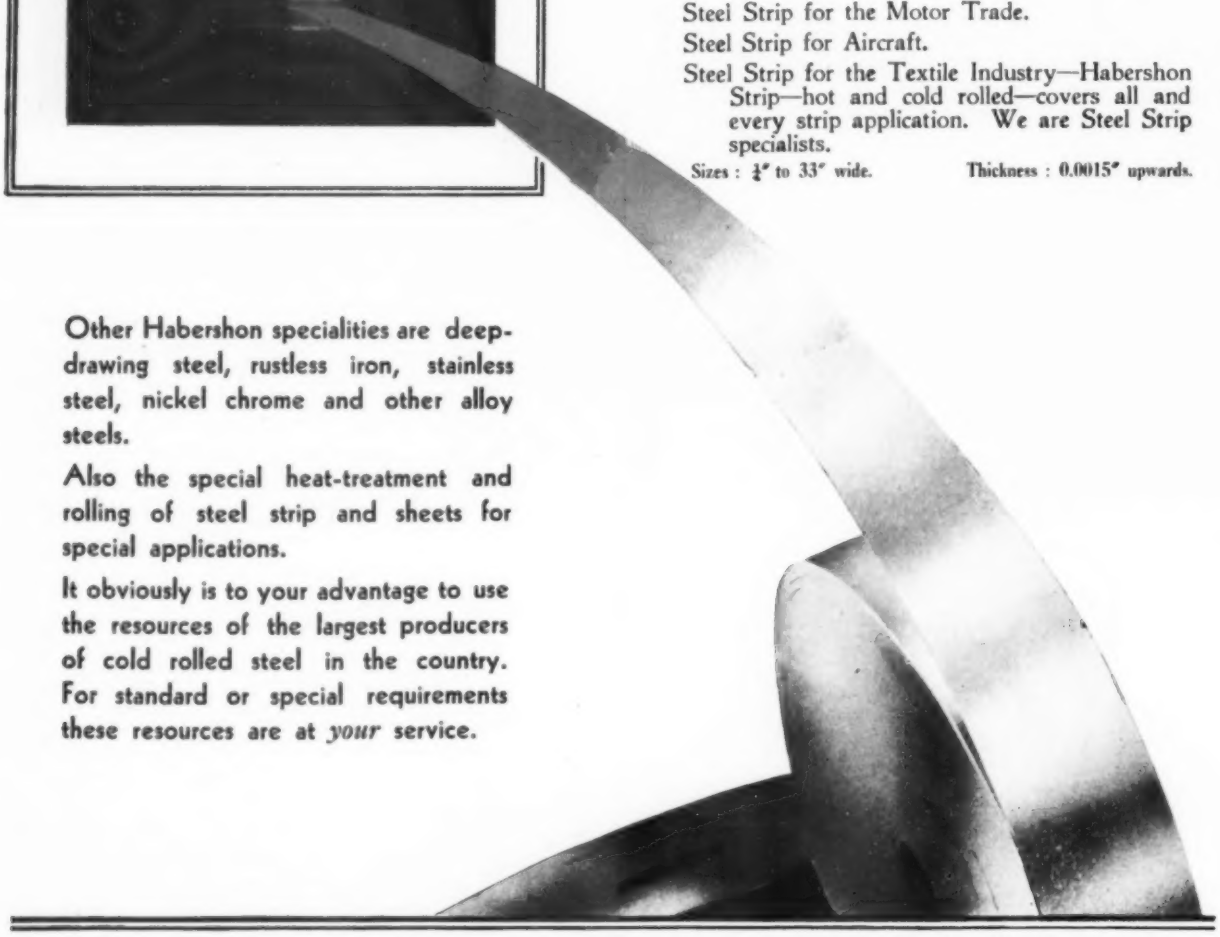

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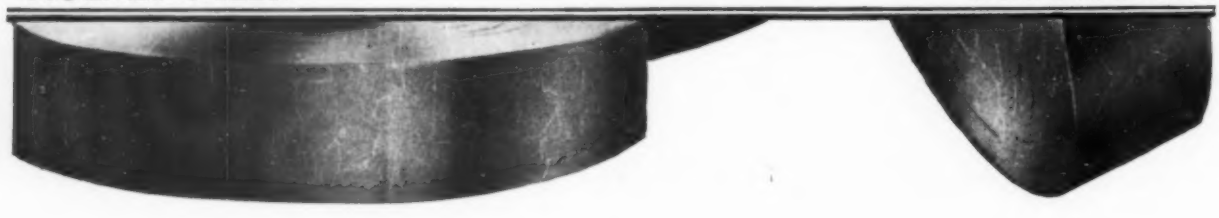

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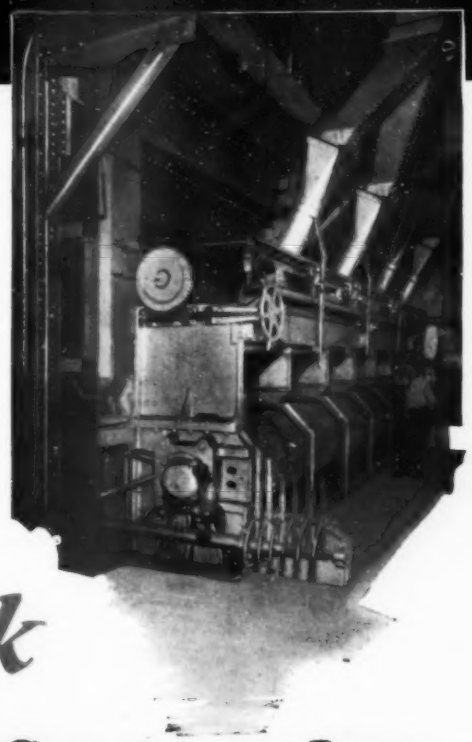

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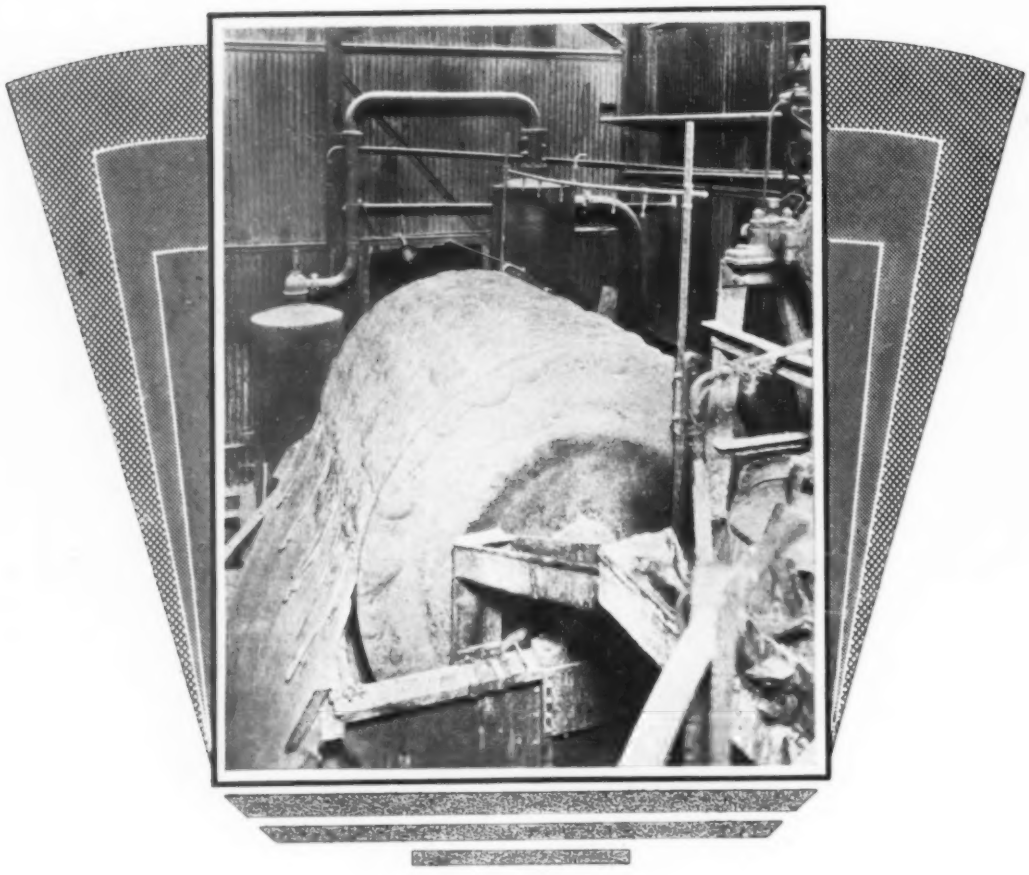

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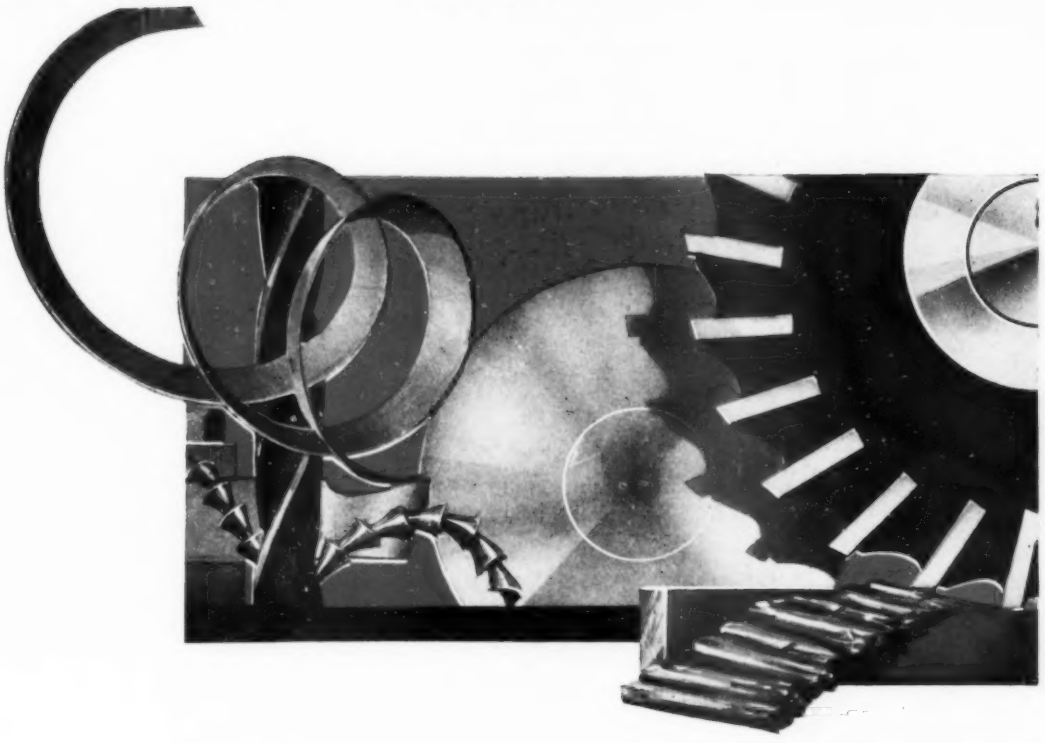

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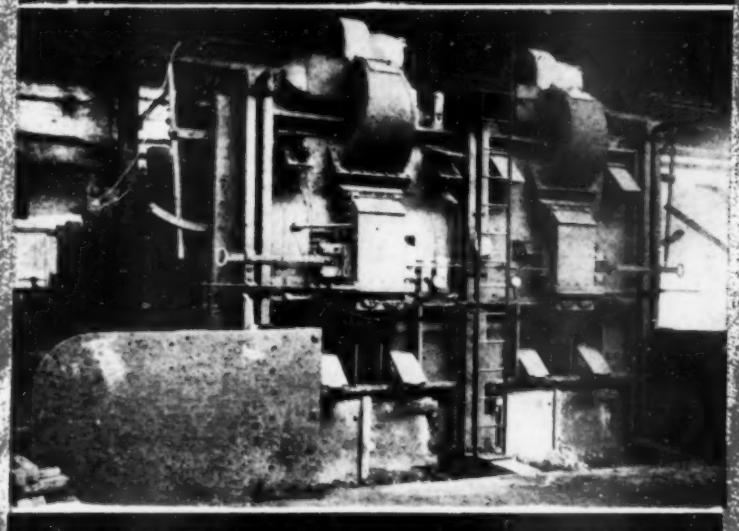

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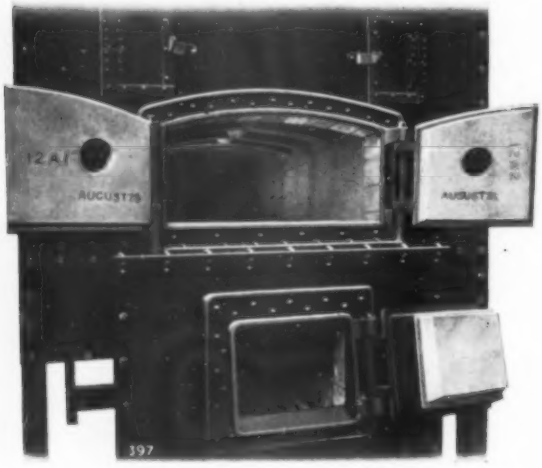

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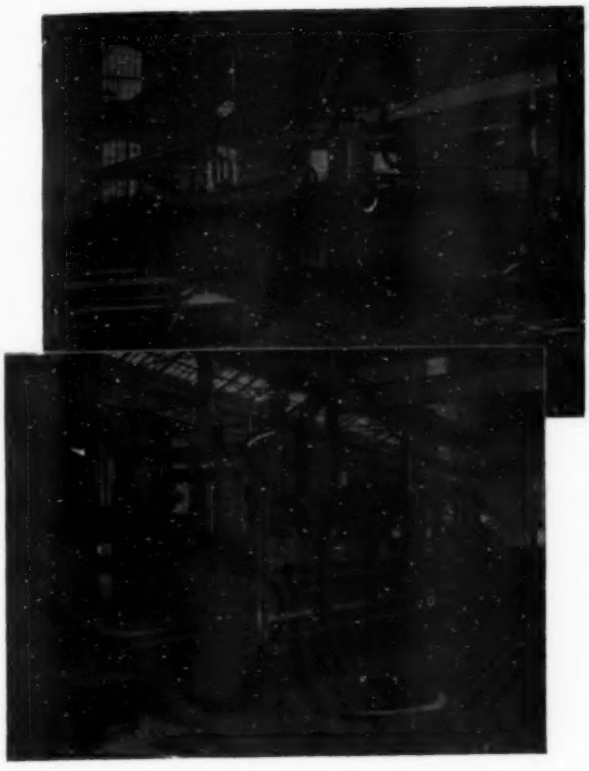

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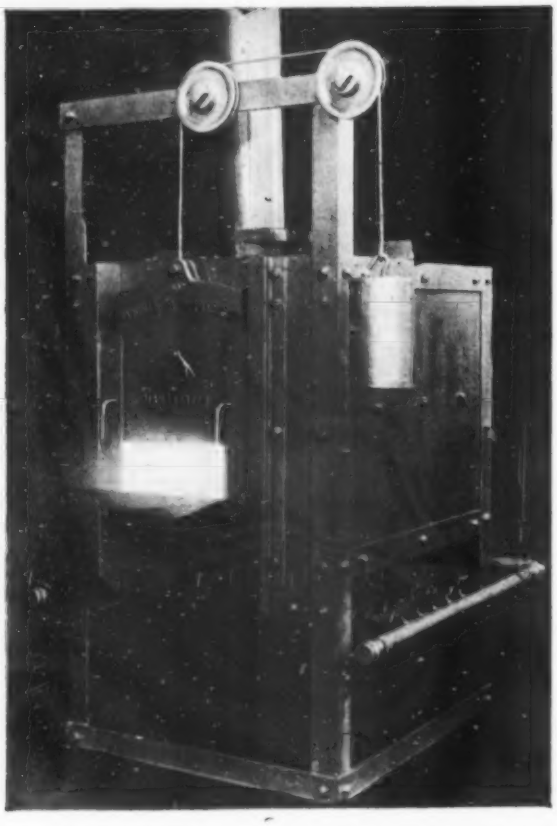

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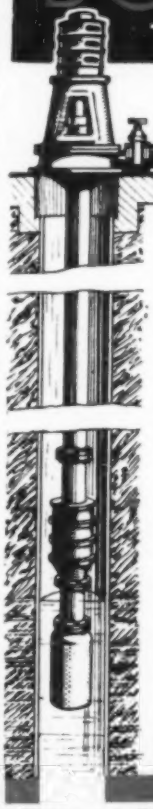

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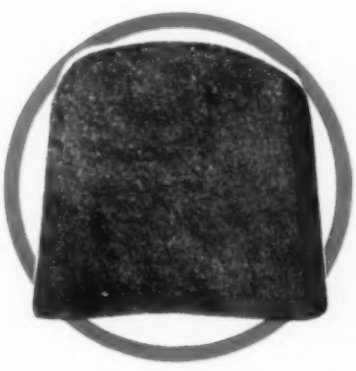

FOR GREY IRON CASTINGS

Grade.	T.C.	Si.	Mn.	P.	S.
C7	2·6/2·8	2·0/2·2	0·5/0·8	0·5/0·8	0·050
C1	2·6/2·8	1·5/1·7	0·5/0·8	0·5/0·8	0·060
D2	2·6/2·8	1·2/1·4	0·8/1·0	0·4/0·6	0·070
E1	2·6/2·8	1·0/1·2	0·8/1·0	0·2/0·4	0·080
F2	2·6/2·8	0·8/1·0	1·0	0·10	0·080

The above irons can be supplied with carbon from 2·8/3·0 or 2·6 maximum, and are only given as representatives of the grades manufactured. A complete list of the grades of "New Process" iron will gladly be sent on request.

Advantages:

1. **Low Carbon** offsets the carbon pick-up experienced in remelting and ensures tough, close-grained, easily machined castings of remarkably fine texture.
2. **Extremely fine graphite,** owing to the iron being superheated in manufacture.
3. **Less shrinkage** in finished castings owing to the range of analysis offering a correct control of composition.
4. **High physical tests** hitherto unobtainable.
5. **Consistent quality.**
6. **Degasification,** giving good castability and soundness.
7. **Guaranteed analysis** to specification.

FOR MALLEABLE IRON CASTINGS

Grade.	T.C.	Si.	Mn.	P.	S.
M1	2·8/3·0	1·0	0·3	0·1	0·08
M2	2·8/3·0	0·8	0·3	0·1	0·08
M3	2·8/3·0	0·6	0·3	0·1	0·08
M4	2·6/2·8	1·0	0·3	0·1	0·08
M5	2·6/2·8	0·8	0·3	0·1	0·08
M6	2·6/2·8	0·6	0·3	0·1	0·08
M7	2·6 max.	1·0	0·3	0·1	0·08
M8	2·6 max.	0·8	0·3	0·1	0·08
M9	2·6 max.	0·6	0·3	0·1	0·08

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Advantages:

1. **Low carbon,** in complete solution during manufacture, with balanced silicon content, gives quicker annealing time.
2. **Iron on annealing shows extremely fine, well-disseminated, nodular graphite,** giving extremely tough malleable, with high resistance to shock.
3. **Low sulphur,** giving a better "malleable," particularly shown by high elongation on tensile test.
4. **Low sulphur** giving a less stable carbide, with saving in annealing.
5. **Less shrinkage** in finished castings owing to the range of analysis offering a correct control of carbon and silicon contents.
6. **Degasification,** giving good castability and soundness.
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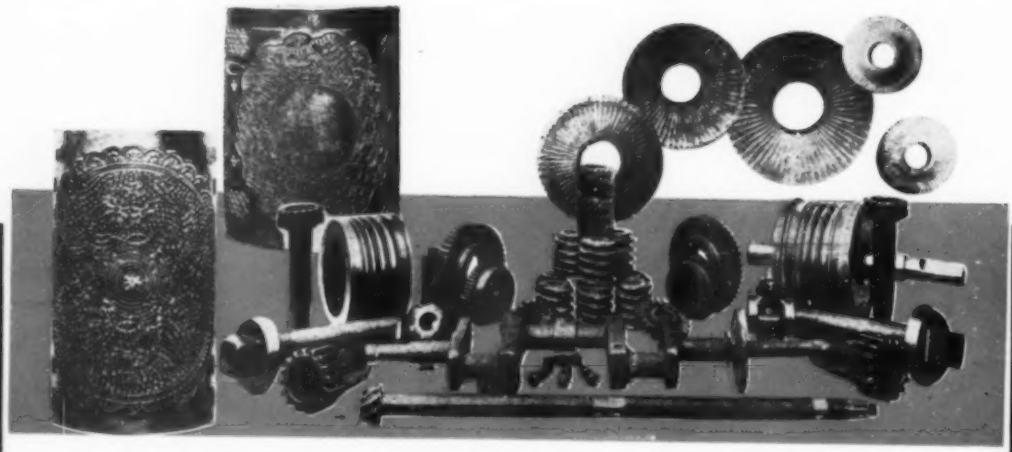

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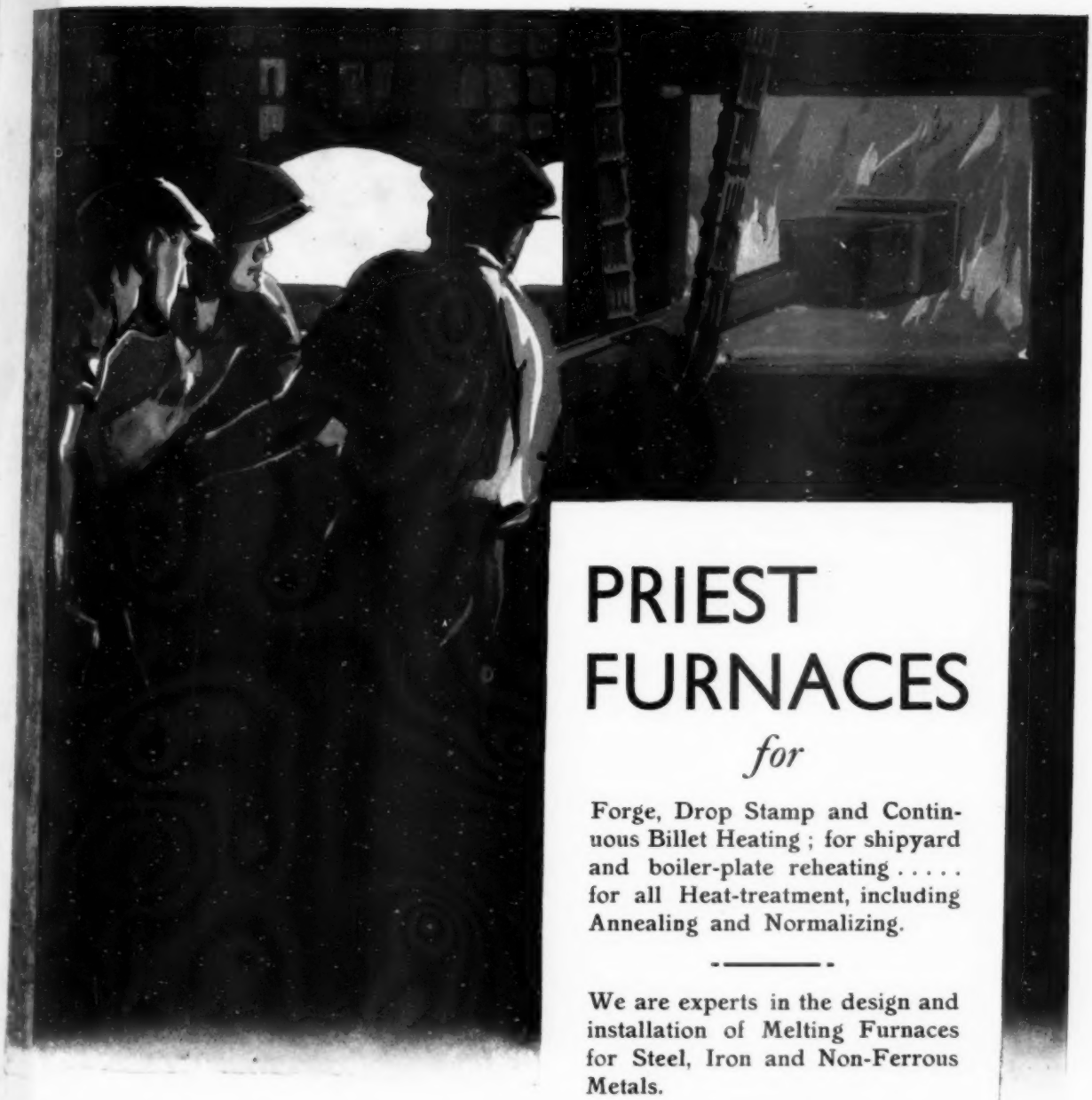

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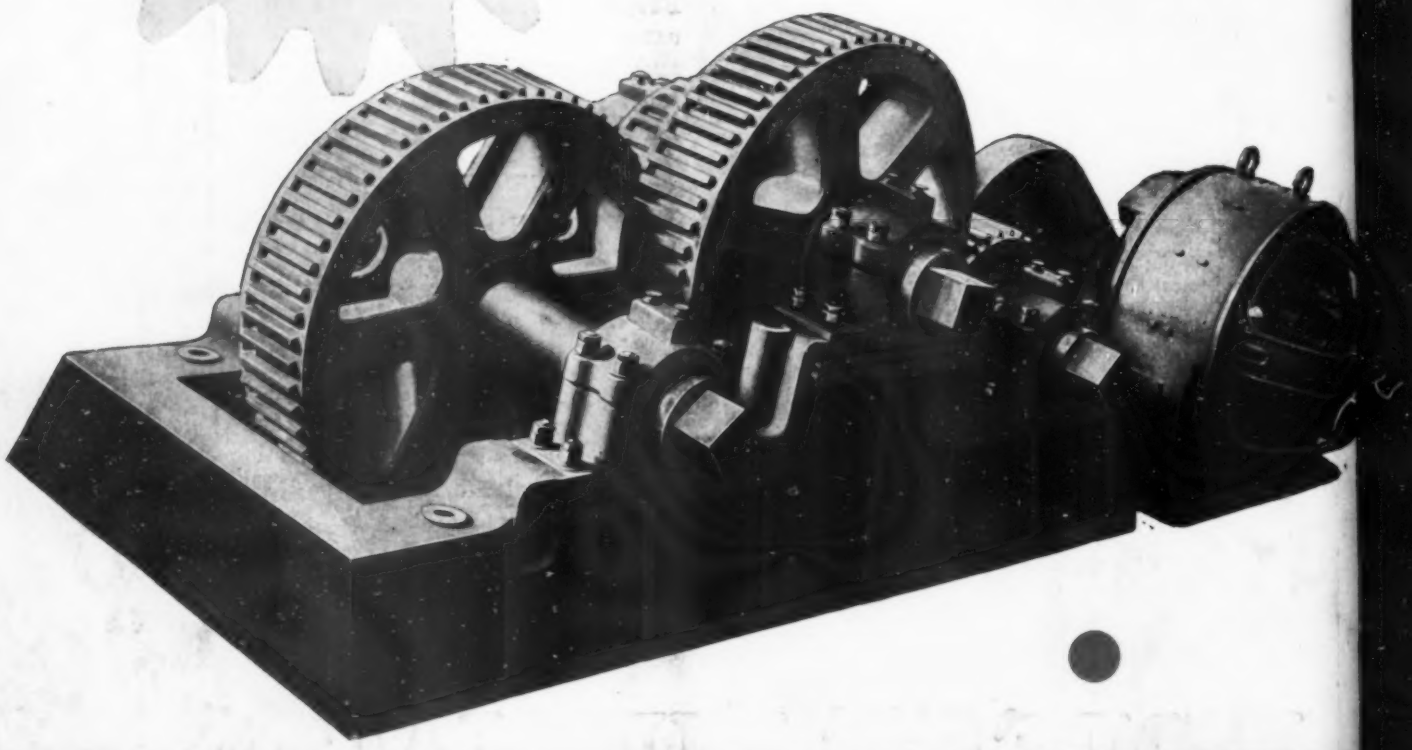

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